Alternative Energy Action Plan

Final Report

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by

Tata Energy Research Institute,
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Team

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CHAPTER 1

Introduction

Background

The Ministry of Environment and Forests, Government of India is preparing Environmental Action Programmes. A number of detailed studies are commissioned from various research institutes to examine different areas of concern. The Tata Energy Research Institute, New Delhi undertook this study to prepare an Alternative Energy Action Plan with particular emphasis on energy conservation, demand management and renewable energy technologies These efforts are supported by the UNDP.

Scope

The energy sector in India has grown rapidly The enormous strain under which the expansion has been taking place recently, has not permitted energy sector organizations to attain levels of efficiency that might bring about optimal use of resources at their command. The main issues in the energy sector are an absence of an integrated long-term energy policy for the country. lack of rational pricing of energy supply, increasing foreign exchange outflows, low levels of useful energy availability, increasing energy demand, and low efficiencies of utilization. Some of the specific concerns are briefly mentioned below

- The losses of the State Electricity Boards have been mounting year after year, with the result that they continue to burden the state exchequer to an increasing degree
- Given an excessive control of tariffs and tariff setting by the Government, electricity prices continue to remain irrational. and therefore do not provide economic incentives for efficiency improvements
- A growing scarcity of capital resources and the dominant role of the public sector has made it difficult for the energy sector to receive the benefits of private financing or innovative managerial skills It appears obvious at this stage that a continuation of past trends in this regard may not be satisfactory.
- Increasing oil imports result in greater foreign exchange outflows.

Hence the major considerations in examining the alternative options for energy development are to develop environmentally beneficial alternatives, which will also reduce oil consumption, and overall energy shortages

In Chapter 2, we have examined the situation with regard to primary energy resources like coal reserves, oil and gas potential and hydropower potential. The supply projections for coal, oil and gas, power generation up to the year 2010 have been worked out based on past trends

The potential for renewable energy resources have been examined in Chapter 3, based on past experiences The demand for conventional fuels is analyzed for each of the sectors and the aggregate demand for various fuels in 2010 is estimated in Chapter 4

The major actions during the first six plan periods are summarized to give a historical account of the growth of energy sector in the country The concerns expressed by the various working groups and the recommendations made by them to address these concerns reflect the thinking in the energy sector. A review of the Eighth Plan concludes Chapter 5 and provides a background for formulating alternative energy strategies.

Two mutually independent, environmentally beneficial alternative strategies are proposed Chapter 6 examines the effects of conservation and demand management measures on the BAU strategy. Chapter 7 focuses on the increased use of renewable energy resources The different programmes and projects to aid in the implementation of these strategies are proposed in Chapter 8

CHAPTER 2

Conventional energy supply

In this chapter the status of different coal, oil and gas, and hydropower resources in the country is presented The supplies of conventional, commercial energy sources like coal, hydrocarbons and electricity in the past decade or more have been normally constrained by availability of resources [1] This fact and detailed energy supply expansion programmes consistent with the current development strategy (CDS) - same as business as usual (BAU) strategy - have been taken into account while projecting energy supply to the year 2010 under the 5% growth scenarios

2.1 Coal and Lignite

Coal is the mainstay of India's energy economy, and is expected to remain so in the foreseeable future Total coal reserves are estimated[2] at about 186 billion tonnes (Table 2 1.1) The Eighth plan estimate is 196 billion tonnes. The major workable deposits of coal occur in a great succession of fresh water sediments, commonly known as "Gondwana" coals of permian age (215 million years old) These reserves constitute nearly 99 5% of the total coal resources of the country Major coal deposits are in Bihar, West Bengal and Orissa, Madhya Pradesh, and Andhra Pradesh The remaining 0.5% deposits of coal of the tertiary age (25-60 million years old) are found in the North-eastern states. The lignite deposits of the tertiary age are in Tamil Nadu, Gujarat, Rajasthan and Kashmir Differences in the geological age are accompanied by differences in the chemical composition; the Gondwana coals being largely bituminous, and the tertiary coals largely lignite The bulk of the present economically viable coal reserves is confined to a 14369 sq km area, distributed amongst 57 peninsular Gondwana coalfields, while tertiary reserves are concentrated in 180 sq. km (14 coalfields) of North- eastern India

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[1] These influence investment levels in various economic sectors (especially energy supply) in each five year planning period given the economic framework of the country where public sector investments are in the critical sectors

[2] Coal reserves available in the country is assessed and updated on a continuous basis by the Geological Survey of India (GSI) through regional mapping and exploratory drilling Detailed drilling is done by the Central Mine Planning and Design Institute Ltd (CMPDIL) the Mineral Exploration Corporation (MEC) and the respective State Governments Since the nationalisation of the coal industry in the early 1970s exploration activity has increased significantly

The salient features of the reserves are as follows:

1. reserves under the proven category are only 30% of the total reserves,
2. about 63% of the total reserves occur at depths of 300 metres or less, and 27% occur in the depth range of 300 metres to 600 metres. Only about 10% of the reserves occur beyond 600 metres depth, and are mainly located in deep coal basins like Raniganj, Jharia, South Karanpura, East/West Bokaro and Godavari coalfields,
3. prime coking coal reserves are restricted to Jharia coalfields, and are less than 3% of the total reserves. However, coal deposits that are close to prime coking coal in characteristics have been located in East/West Bokaro and parts of Sohagpur coalfields;
4. reserves of medium coking and semi-coking coals constitute about 13% of the total reserves,
5. reserves of superior non-coking coals (grades A, B, and C) are limited (about 12% of total reserves), with the major deposits lying in the Raniganj coalfields Sizeable reserves are also available in Talcher, Korba, South Karanpura, Chirimiri and a few other coalfields Substantial reserves of deep-seated superior quality coal have now been identified in Birbhum and Domra-Panagarh areas of West Bengal; and
6. the bulk of the coal reserves in the country (73%) are inferior grade non-coking coals, occurring largely in thick interbanded seams and located in coalfields like Singrauli, Ib Valley, Talcher, North Karanpura, Rajmahal, Korba, Wardha and so forth

Table 2.1.1. Coal reserves as on 1 January 1990 (billion tonnes).

Type of Coal	Proved	Indicated	Inferred	Total
Coking Coal				
Prime	4.23	1.07	-	5.30
Medium	9.37	10.99	1.23	21.59
Semi	0.55	0.91	0.62	2.08
Sub-total	14.15	12.97	1.85	28.97
Non-Coking Coal	42.14	68.41	46.52	157.07
Total	56.29	81.38	48.37	186.04

Source: "Personal Communications", Geological Survey of India, 1991

The actual production potential is dependent not on *geological* reserves, but on *mineable* and *recoverable* reserves.[3] According to Government of India (1988c), about 99.2 billion tonnes of mineable reserves are available for future projectisation. A break-up of this estimate of mineable reserves under broad depth and quality classes is given in Table 2.1.2

The mineable reserves are derived on the following basis

(a) The certainty equivalent of proven, indicated and inferred reserves (0.9 for proven 0.65 for indicated and 0.3 for inferred), and

(b) blockage of coal reserves for different geophysical conditions such as underground fires water township railways roads etc

Table 2.1.2. Mineable and recoverable reserves (billion tonnes)

Type	Depth				Total	
	0-300 m		> 300 m			
	MR*	RR#	MR	RR	MR	RR
Coking Coal						
i) Prime	0 40	0.22	1.90	0 96	2 30	1 18
ii) Medium	6 98	4.01	6 64	3 10	13 62	7.11
iii) Semi	0 38	0.24	0 58	0.37	0.96	0 61
Sub Total	7 76	4.47	9.12	4 43	16.88	8 90
Non-Coking Coal						
i) Superior	10 95	6.76	5.24	2.65	16.19	9.41
a) A & B					2.75	1.38
b) C & D					13.44	8 03
ii) Inferior	47.68	29 87	18.14	8.30	66.09	38.77
Sub Total	58.63	36.63	23.65	10.95	82.28	47.58
	66 39	41 10	32.77	15.38	99 16	56.48

Source GOI (1988c).
* MR : Mineable Reserves, # RR Recoverable Reserves

The recoverable reserves based on certain recovery factors for various coalfields and depth-thickness combinations have been worked out by the Planning Commission (1988) A total of 36 6 billion tonnes of non-coking coal and 4 47 billion tonnes of coking coals are mineable from depths of less than 300 metres, using open-cast mining methods

The lignite reserves are rather limited the proven and inferred reserves together being 8 5 billion tonnes

Supply projections

The share of coal produced from open-cast mining (using both the shovel-dumper and drag-line techniques) has increased steadily since the mid-1970s, and reached a level of about 64% in 1989/90 This trend is anticipated to continue, and the share from open-cast mines is expected to rise to 67% by 1994/95, 70% by 1999/2000 and 73% by 2004/05. This share is assumed to stabilize at 73% after 2004/05, largely because of the poor quality of coal produced by the adoption of this technology -- free dirt, boulders and other lumpy extraneous matter also get mined along with coal.

Available data from 1980/81 through 1988/89 show that on the average, investment in the coal mining industry accounted for 0.47% of GDP. Maintaining this level of investment in the future, the total investment in the coal industry is projected to increase from about Rs. 2000 crores (1990/91 prices) in 1990/91 to Rs. 5000 crores(1990/91 prices) in 2009/10, i e. at the rate of about 5% per annum. Table 2.3 gives the projected levels of investment in the coal industry to the year 2009/10

Available data also show that the investment required to create 1 million tonne per annum (mtpa) mining capacity is different for open-cast and underground mines. Open-cast mines, which are mechanized, entail an average investment cost of Rs 134 crores/mtpa capacity. Mechanized underground mines require about Rs 181 crores/mtpa capacity However, not all new underground mines commissioned in recent years have been fully mechanized -- the non-mechanized ones are less capital intensive As a result the average capital expenditure incurred on underground mines in the past three years has been Rs 120 crores/mtpa. It is assumed that the average level of mechanization of underground mines will increase gradually (as the productivity, measured in tonnes of coal output per man-shift, is higher than in non-mechanized mines) to reach full mechanization by the year 2004/05. Moreover, owing to the rapid increases in costs of mining equipment, the real term investment requirements per mtpa of mining capacity are further expected to escalate by 2% per annum

Table 2.1.3 Coal sector investment projections

(Rs crore 1990/91 prices)

Year	Investment projection	Year	Investment projection
1989/90	1865 9	2001/01	3191.2
1990/91	1959.1	2000/02	3350.9
1991/92	2057.0	2002/03	3518.5
1992/93	2160 0	2003/04	3694.3
1993/94	2268.0	2004/05	3879.0
1994/95	2381.4	2005/06	4073.0
1995/96	2500.4	2006/07	4276.6
1996/97	2625.5	2007/08	4490 5
1997/98	2756.7	2008/09	4714.9
1998/99	2894.6	2009/10	4950 7
1999/00	3039 3		

On this basis fairly rapid increases in coal production have been projected -- from about 209 million tonnes (MT) in 1988/89 to 573 MT in 2009/10 -- an average growth rate at the rate of 5 2% per annum. The all-India production of coal has been further divided over the regions on the basis of the percentage share of total coal reserves in each region These are further split between coking and non-coking coal production on the basis of the share of coking and non-coking coal reserves in each region The results are presented in Table 2 1 4

Table 2.1.4. Coal -- Regional break-up of production of coking and non-coking coals (MT)

		Actual	Projections			
UC/OG	CC/NCC	1989/90	1994/95	1999/00	2004/05	2009/10
WR	**Total**	75 16	86.71	99 17	113.99	125.87
OC	CC	0 90	1 18	1 47	1 78	2 01
OC	NCC	54 09	70 92	88 44	106 85	120.61
UG	CC	2 50	1 81	1 15	0.66	0.40
UG	NCC	17 67	12 80	8 11	4 69	2.85
SR	**Total**	17 80	36 76	42 37	47 33	47.84
OC	CC	-	-	-	-	-
OC	NCC	7 54	23 36	29 44	35 95	37.51
UG	CC	-	-	-	-	-
UG	NCC	10 26	13 41	12 93	11 38	10.33
ER	**Total**	102 45	157 96	223 84	301 18	395.88
OC	CC	16 64	25 63	37 55	53 29	70 65
OC	NCC	43 40	66 84	97 90	138 95	184 22
UG	CC	20 66	31 90	43 06	53 07	68 69
UG	NCC	21 75	33 59	45 34	55 88	72 32
NER	**Total**	1 20	3 04	4 34	3 93	3 70
OC	CC	-	-	-	-	-
OC	NCC	0 84	2 67	4 01	3.68	3 50
UG	CC	-	-	-	-	-
UG	NCC	0 36	0 38	0 33	0 25	0 20
All India						
OC	CC	17 54	26 82	39 02	55 07	72 66
OC	NCC	105 87	163 79	219 78	285 43	345 84
UG	CC	23 16	33 71	44 20	53 73	69 09
UG	NCC	50 04	60 18	66 71	72 20	85 70
Total		196 61	284 48	369 71	466 44	573.29

Note NER-North-eastern Region, ER-Eastern Region, WR-Western Region SR - Southern, Region, OC-Opencast, UG-Underground, CC - Coking Coal, NCC-Non Coking Coal

All non-coking coals produced from open-cast mines are of inferior grade (referred to as INCC or inferior non-coking coals), and those produced from underground mines are of superior grade (referred to as SNCC or superior non-coking coals) INCC include "E", "F" and "G" grade coals,[4] while SNCC will generally be of "A", "B", "C" and "D" grades.[5] Table 2.1.4 shows that total coal production (CC or coking coals plus INCC plus SNCC) is concentrated in the Eastern Region While in 1989/90, the Eastern Region accounted for 49 1% of total coal production in the country, this share will increase gradually to 69.1% by 2009/10 The rate of increase of coal production in the Eastern Region is 7% per annum from 1989/90 to 2009/10, compared to 5 2% for the entire country Although total coking coal production is projected to increase to over 140 MT by 2009/10, a major portion of this will comprise poor quality medium and semi/ weakly coking coals -- which would be more suitable for use as industrial/utility boiler fuel.

It is assumed that lignite production, as a percentage of total coal production, will remain the same as in recent years (after 1985/86), i.e. at 5.7%. Further, as bulk of the lignite reserves are in the Southern Region (Tamil Nadu), a large share of lignite production will remain there Table 2.1.4 summarizes the region-wise projections of lignite production In the Southern Region, the lignite production is projected to increase to 34.51 MT in 2009/10, and in the Western and Northern Regions to 2 18 MT each

According to Department of Coal, it may not be possible, for geological reasons, to sustain an annual coal production level of beyond 550 to 600 million tonnes

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[4] "E" grade ash plus moisture content (AMC) of 32 to 35% useful heat value (UHV) of 3360 4200 kCal/kg median gross calorific value (MGCV) of 4700 kCal/kg

"F" grade AMC above 35% UHV = 2400 3600 kCal/kg MGCV = 4000 kCal/kg
"G" grade AMC above 35%, UHV = 1300 - 2400 kCal/kg MGCV = 3300 kCal/kg

[5] "A" grade AMC less than 17% UHV above 6200 kCal/kg MGCV = 6300 kCal/kg
"B" grade AMC of 17 19%, UHV = 5600 - 6200 kCal/kg MGCV = 6100 kCal/kg
"C" grade AMC of 19 24% UHV = 4940 5600 kCal/kg MGCV = 5700 kCal/kg
"D" grade AMC of 24 32% UHV = 4200 4940 kCal/kg MGCV = 5200 kCal/kg

Table 2.1.5 Lignite -- Regional break-up of production (MT)

Region	1989/90	1994/95	1999/00	2004/05	2009/10
NR	0	0	0.56	1.27	2.18
WR	1.33	1.86	1.96	2.07	2 18
SR	10.53	14 75	19.96	26 43	34.51
Total	11.86	16.61	22 48	29 77	38 86

2.2 Oil and Natural Gas

Hydrocarbon resources

The total area of sedimentary basins in India is about 1 72 million square km, of which 1.4 million square km are on land, the remaining area is offshore, within the 200 metres isobath line. Out of the 26 sedimentary basins 13 are of geological interest. The total prognosticated hydrocarbon resources are estimated at 21 billion tonnes of oil and oil equivalent of gas(Table 2 2 1) Approximately 11.3 billion tonnes are in Category I basins and the rest are in Category II and III basins [6]

The proven and indicated balance recoverable reserves of crude oil are 5320 million tonnes, half of which may be natural gas (Eighth Plan) Only 12% of natural gas has been established These reserves are located mainly along the West Coast between the Gulf of Cambay and Bombay and in the North-eastern region in Upper Assam, and may be disaggregated as follows

(a) Bombay High offshore basin 450 million tonnes of crude oil and 457 billion cubic metres (bcm) of gas,

(b) Cambay basin 162 million tonnes of crude oil and 93 of natural gas,

(c) Upper Assam basin 145 million tonnes of crude oil and 135 bcm of gas, and

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Category I basins proven petroliferous basins where commercial production has already begun Category II basins sedimentary basins with known occurrence of hydrocarbons, but from which no commercial production has yet been obtained and Category III basins sedimentary basins in which significant evidence of hydro-carbons has not yet been found, but which, on general geological grounds, are considered possible

(d) Rajasthan: 1.04 bcm of gas. A part of the natural gas occurs as associated gas, the production of which is related to oil production

Table 2.2.1. Prognosticated hydrocarbon resources

Resources	Prognosticated Ratio (mtoe)	Gas-Oil (cu m/t)
Onshore	7772	
Cambay	1650	249.9
Upper Assam	2280	476.3
K. Godavari	217	2796.5
Cauvery	166	835.1
Bengal	326	835.1
Assam-Arakan	2110	820.6
K Saurashtra	263	835 1
HF & G. Valley	370	835 1
Rajasthan	340	4784 7
Mahanadi	50	835 1
Offshore	12773	
K. Godavari	543	549 8
Cauvery	374	829.1
Bengal	634	1813.5
K. Saurashtra	497	436.9
Kerala-Konkan	1630	2919.2
Mahanadi	1240	1820.3
Andaman	465	1820.3
Bombay High	7390	455.8

Source: "Personal Communications", Department of Petroleum and Natural Gas, 1991

While most of the exploration until 1979 was concentrated in Category I basins, exploration in category II and III basins accelerated substantially in the 1980s In the Seventh Five-Year Plan period (1985/86 to 1989/90), nearly half of the exploratory effort was in Category II and III basins. In the Eighth Plan intensive exploration in Category I basins is proposed

Efforts are being made to improve recovery factors from the producing oil fields. The necessary R & D efforts are under-way, and pilot projects using various enhanced oil recovery (EOR) techniques have been initiated. In particular, thermal methods (such as in-situ combustion and steam flooding) and chemical injection methods (such as polymer/micellar-polymer/ caustic flooding) of EOR have been tried Preliminary results indicate over 10% of additional recovery in all pilot tests.

Supply of Hydrocarbons

Although the development of the indigenous oil industry has received high priority since the mid-1970s, only about 25% of the prognosticated hydrocarbon resources have been proven so far As the exploratory effort is in the initial stages in several basins, geological information required for making reasonable projections on the success of exploratory activity may not be available even with the oil industry. Therefore, the approach adopted is to use normative data for different basins on average gas-oil ratios (GOR), expected discovery index (EDI), indicative costs per metre for exploratory and development drilling and so forth (Table 3 4).

Table 2.2.2 Hydrocarbons Petroliferous basin particulars

(1990/91 prices)

	Prognosticated Resources (mtoe)	R/P Ratio	Total Dev Drilling Cost (Rs/metre)	Expected discovery index (Tonnes/metre)	Direct Exploratory Drilling Cost	Gas Oil Ratio (cu m/tonne) (Rs/metre)
Onshore	7772					
Cambay	1650	10	10917	188	5585	249.9
Upper Assam	2280	15	12665	750	11641	476.3
K Godavari	217	15	16702	286	25978	2796.5
Cauvery	166	15	10917	273	25978	835.1
Bengal	326	15	18670	215	21361	835.1
Assam Arakan	2110	15	18670	335	17986	820.6
K Saurashtra	265	15	10917	257	5585	835.1
HF & G Valley	370	15	18760	260	17986	835.1
Rajasthan	340	15	10917	220	20520	4784.7
Mahanadi	50	15	18760	215	9128	835.1
Offshore	12775					
K Godavari	545	15	46325	1374	49696	549.8
Cauvery	374	15	43181	643	49696	826.1
Bengal	634	15	46325	845	49696	1815.5
K Saurashtra	497	15	46325	832	49696	436.9
Kerala Konkan	1630	15	39260	696	49696	2019.2
Mahanadi	1240	15	46327	843	49696	1820.3
Andaman	465	15	[illegible]	910	49696	1820.3
Bombay High	7390	15	39265	1701	39985	455.6

Source. GOI (1988) and Ministry of Petroleum and Natural Gas

Indicative values of direct exploratory drilling costs per metre for each basin are obtained from GOI (1988) Direct drilling costs account for 58% of total exploratory drilling costs in onshore areas, and 32% in offshore areas [GOI (1989)]. Assuming that exploratory drilling in 2009/10 is in line with present estimates of resource prognostications, it is estimated that the overall average cost of exploratory metre drilled in the year 2009/10 will be Rs 91472 (1990/91 prices) Total investments in exploration are first projected to 2009/10, along with drilling costs per metre in onshore and offshore areas Available data on total investment in hydrocarbon subsector in the 1980s, and projected investment levels as per GOI (1989) indicate that about 0.57% of GDP is earmarked for exploration activity -- which is used as a basis for projecting investments for exploration work (Table 2.2.3) As total investment in exploration in 2009/10 is projected at about Rs. 6114 crores the total exploratory drilling will be 668,350 metres Given the exploratory drilling in various basins in 1988/89, the metreage is interpolated basin-wise.[7]

The basin-wise expected discovery index is then used to compute the annual reserve additions, the prognosticated resources of free gas are treated separately from oil/associated gas reserves. About 25% of the oil and associated gas reserves and 65% of the free gas reserves are estimated to be recoverable To compute the yearly hydrocarbon production levels basin-wise, an iterative procedure is adopted, keeping in view that·

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[7] It is assumed that the exploratory drilling begins in 1990/91 in the Kutch-Saurashtra (onshore and offshore) basins and in 1995/96 in the Kerala-Konkan (offshore), Andaman (offshore) and Mahanadi (onshore and offshore) basins

(a) the reserves to production (R/P) ratio of oil and associated gas in each basin at the end of 2009/10 should remain at the levels given in Table 2.2.2; and

(b) commercial production from a basin begins five years after the first successful exploratory well is drilled. Further, as the potential to produce free gas is high (about 85% of all possible gas production will be free gas), it is assumed that its production will be curtailed so that total gas production equals gas demand, and flaring becomes negligible.

Table 2.2.3 Hydrocarbons - Projections of investment levels

(Rs crore 1990/91 prices)

	Exploration	Production/Development
1990/91	2419	1309
1994/95	2941	1591
1999/00	3753	2031
2004/05	4790	2592
2009/10	6114	3308

Total oil and associated gas outputs and free gas production potentials are aggregated region-wise Table 2.2.4 presents projected levels of oil and associated plus free gas production potentials Oil production increases from 30.63 mtoe in 1990/91 to 70.49 mtoe in 2009/10, at the rate of 4.48% p.a ; gas production potential increases faster from 18.10 billion cubic metres (bcm) to 68.27 bcm, at the annual average growth rate of 7.24%

Table 2.2.4 Hydrocarbons -- Projections of Oil and Gas production

		1990-91	1994-95	1999-00	2004-05	2009-10
A. Oil production (MT)						
Onshore	NR	0.00	0.00	0.00	0.04	0.39
	NER	5.35	6.11	7.34	9.11	11.90
	ER	0.00	0.00	0.00	0.03	0.26
	WR	4.77	5.03	5.38	5.75	6.19
	SR	0.12	0.17	0.26	0.42	0.79
Offshore	ER	0 00	0.00	0.00	0.04	1.00
	WR	20.24	23.97	29.62	36.60	45.66
	SR	0.15	0.28	0.59	1 34	4.31
Total		**30.63**	**35.55**	**43.19**	**53.32**	**70.49**
B. Gas production potential (bcm)						
Onshore	NR	0.00	0.00	0 02	0.22	2.27
	NER	3.60	4.65	7.24	9.98	12 25
	ER	0.00	0 00	0 01	0 05	0 41
	WR	1.57	1.84	2.47	2.78	2.66
	SR	0.15	0.24	0.51	1.12	3.04
Offshore	ER	0.00	0.00	0 01	0.22	4.55
	WR	12.66	16.67	25.86	33.69	36.69
	SR	0.12	0.24	0.64	1 58	6.40
Total		**18.10**	**23.63**	**36.75**	**49.64**	**68.27**

To estimate investments for oil field development activity, the investment in capital equipment required at oil field sites (oil/gas gathering stations, gas-oil/water oil separators etc.) is limited to developmental drilling costs This is done basin-wise and the results are given in Table 2 2 2 It is estimated that development drilling nearly doubles from less than 0 6 million metres in 1990/91 to about 1.1 million metres in 2009/10.

While refining capacity will also increase in absolute terms, its share is assumed to decrease from about 92% of total demand for refined products in 1989/90 to below 75% in 1994/95 and remain at that level to the year 2009/10. As per present expectations, the refining capacity by March 1995 will increase to 61.815 million tonnes per annum (mtpa) which implies that refining capacity will meet about 73% of product demand Capacity utilization is assumed at 90% and losses at 6% of the crude throughput For every 6 mtpa of refining capacity that is added, 1 mtpa of fluidized catalytic cracker (FCC) and 1 mtpa of hydro- cracker (HC) capacity will also be added.[8] Investments in refineries are estimated at Rs. 2009 crores, Rs 3319 crores, Rs. 3973 crores and Rs 5560 crores during the four successive five-year intervals from April 1990 to March 2010; with capacities assumed to increase from 49.8 mtpa to 138.4 mtpa by March 2000.

Normative capital investment data on natural gas pipelines, obtained from the Gas Authority of India Ltd (GAIL) are : (i) for new pipelines on land, about Rs. 1350 per standard cubic metre per day (SCMD) of gas throughput capacity, (ii) for expansion of throughput of existing pipelines on land, Rs. 1000/SCMD; and (iii) for construction of pipelines offshore (including requisite gas processing facilities etc), Rs. 1285/SCMD. Along with the estimates of increased gas production and demand, investment on pipelines are computed and presented in Table 2 2 5. It may be noted that investment in onland gas pipelines is related to demand for gas, while for offshore pipelines, to production of gas from offshore areas

Table 2.2.5 Investment in natural gas pipelines

(Rs. crore, 1990/91 prices)

	1990/91 to 1994/95	1995/96 to 1999/00	2000/01 to 2004/05	2005/06 to 2009/10
Onland	3895	4300	3222	5060
Offshore	2329	1332	1804	4554
Total	6224	5632	5026	9614

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[8] It is assumed that minor light distillates will account for 2 65% of total production of light distillates, minor middle distillates for 1 2% of all middle distillates, and minor heavy ends for 22 5% of all heavy ends

2.3 Power Generation

Hydro resources

According to available data, India's total economically exploitable hydroelectric potential is 396.4 TWh of annual energy generation, or about 75,400 MW at 60% load factor Approximately one-fifth of this potential has been developed so far. Most of the unexploited potential is concentrated in the Northern and North-eastern regions (about 48,000 MW). Low demand for electric power impedes development of hydroelectric projects in the Northeast Over 60% of the potential in the Southern Region has been developed so far

Hydropower development is now being increasingly integrated into optimal river valley development programmes Several multi-purpose projects with hydroelectric power as one of the components (the other being surface irrigation) have been developed. The first such project was in the Cauvery basin at Mettur in the Southern Region

While the advantages of hydropower are well recognized, the exploitation of hydropower resources has been constrained by several factors These include differences in inter-state priorities, long gestation periods, financial constraints, and problems of land submergence and resettlement of affected population

The fact that hydropower development has not kept pace with the demand for power is a cause for concern. Given the Indian energy situation, it is necessary to restore the confidence in hydro development, ensure availability of modern technology for investigation and construction of hydro projects, rationally view the concerns of environmentalists and carefully select some major sites for early development

One possibility is small hydropower development No reliable estimates of the potential for small hydro are available. Some idea of the potential can be obtained from the estimates made by the Rural Electrification Corporation (REC) based on surveys in the mid 1980s for small hydro power generation potential on existing irrigation systems in the country Over a thousand sites were identified on existing irrigation dams, canal drops, diversion weirs, etc. and the potential was estimated at over 5,000 MW The REC survey highlighted the concentration of projects in the southern states of Andhra Pradesh, Karnataka and Tamil Nadu where the potential was placed at 2000 Gwh of energy annually at 500 sites

Power supply projections

The power supply industry in India is one of the fastest growing subsectors The organized Indian power supply industry has accounted for 16% to 18% of total public sector investments since the mid-1970s, and 2.2% to 2 5% of GDP in the 1980s Such high dependence on planned budgetary resources may not be sustained to 2010, but significant private sector investment is expected It is estimated that about 25150 MW of new capacity will be added between April 1990 and March 1995, about 29750 MW from April 1995 to March 2000, 34480 MW from April 2000 to March 2005, and 51770 MW from April 2005 to March 2010.[9] Table 2 3 1 gives the region-wise break-up and by type of capacity As per these projections, the share of hydro capacity falls from 28 7% in March 1990 to about 25 7% in March 2010 These estimates are rather disturbing but have been computed based on existing hydro-thermal mix and investments in the power sector. It is hoped that the target of the Eighth Plan to increase the share of hydel generation to 30% by 1997 and 40% by the end of the Ninth Plan is actually achieved The share of total coal-fired thermal capacity (with oil support) reduces from 65% to less than 60%, while gas-based turbine (GT) and combined cycle plant (CCP) capacity increases from 3 7% to 9 6%

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[9] According to GOI (1989) about 38000 MW of capacity will come on-stream by March 1995 However as some projects will get delayed it is assumed that all sanctioned ongoing projects and some Central Electricity Authority (CEA) cleared projects will be commissioned by March 1995 while the remaining CEA cleared projects and all "new" projects (that have only been identified until now) will come on stream after 1994/95 As there are very few projects in this shelf that will be commissioned after March 2000 the total capacity additions beyond March 2000 are made up by adding reasonable hydro and other plant capacity (in line with the ratio of additions of various types of generating plant from April 1990 to March 2000) The Eighth Plan document predicts capacity additions to the tune of 35 000 MW between 1992 97

Table 2.3.1 Power generating capacity additions (MW)

		Upto Mar 1990	Apr 1990 Mar 1995	Apr 1995 Mar 2000	Apr 2000 Mar 2005	Apr 2005 Mar 2010
NR	Hydro	5942	1768	5418	5429	3421
	Coal TPS	11140	1790	4520	5940	9440
	GT/CCP	1218	2030	1233	300	477
	Nuclear	675	470	470	1000	1589
	Total	18975	6050	11641	12669	14927
WR	Hydro	2248	1303	250	1223	1900
	Coal TPS	15644	2870	4750	4960	7883
	GT/CCP	717	2398	1845	900	1430
	Nuclear	420	470	0	500	795
	Total	19029	7041	6845	7583	12008
SR	Hydro	8060	1145	1215	598	1431
	Coal TPS	7043	2100	3520	4820	7660
	GT/CCP	30	863	478	290	461
	Nuclear	470	0	470	940	1494
	Total	15602	4108	5683	6648	11046
ER	Hydro	1370	1371	82	1310	2604
	Coal TPS	6654	5285	4020	4548	7227
	GT/CCP	190	0	0	0	0
	Nuclear	0	0	0	0	0
	Total	8214	6656	4102	5858	9831
NER	Hydro	421	371	422	720	2367
	Coal TPS	413	0	0	0	0
	GT/CCP	203	912	1062	1000	1589
	Nuclear	0	0	0	0	0
	Total	1036	1283	1484	1720	3956
All India	Hydro	18042	5957	7387	9279	11723
	Coal TPS	40893	12045	16810	20268	32210
	GT/CCP	2358	6203	4618	2490	3957
	Nuclear	1565	940	940	2440	3878
	Total	62587	25145	29754	34477	51768

Capacity additions envisaged for until March 2000 are estimated largely on the basis of specific projects that have been identified In particular, these include

(a) projects that have already been sanctioned or/and are under construction,

(b) those which have not yet been sanctioned but have at least been cleared in principle by the Central Electricity Authority (CEA), and

(c) those projects or schemes that have only been identified until now, but on which a final decision on financial support (from the Plan budget) is still awaited

The investment norms estimated from data obtained from CEA and Planning Commission are as follows· Rs 17000/kW for hydro capacity, Rs 16000/kW for nuclear, Rs 15000/kW for coal-fired TPS capacity, and Rs 10500/kW for GT/CCP capacity These figures are in 1990/91 prices. Capital costs are also assumed to escalate by 7.5% per annum in real terms up to the year 2000 and 5% thereafter to the year 2010. Although the Government of India (1980) had recommended that 50% of all investment in the power subsector should be for transmission and distribution (T&D) projects, about 60% of the investment in the 1980s was on installing new generation capacity Therefore, it is assumed that 60% of all future planned investments in the power subsector will be for capacity expansion The remainder 40% will be split equally between transmission and distribution

Based on projections for installed capacity, gross and net generation levels are estimated (Table 2.3.2) These are derived as follows :

(a) for hydro power capacity, the gross generation is assumed to be 2900 kWh/kW of installed capacity and auxiliary consumption about 1% of gross generation,

(b) for coal-fired thermal capacity (which uses unwashed coal), annual gross generation is 4900 kWh/kW and auxiliary consumption is 10% of gross generation,

(c) for gas-fired GT and CCP capacity, the gross generation is 7000 kWh/kW with auxiliary consumption being about 2 5% of gross generation, and

(e) for nuclear capacity, the gross generation is 4500 kWh kW with auxiliary consumption being 10% of gross generation

Table 2.3.2. Projections for gross generation, net generation and sales (GWh)

	1994/95	1999/00	2004/05	2009/10
A. Gross generation				
Hydro	69597	91018	117927	151923
Coal TPS	259395	341764	441075	598904
GT/CCP	59925	92251	109681	137381
Nuclear	11273	15503	26483	43932
Total	400190	540535	695165	932141
B. Net generation				
Hydro	68901	90107	116747	150404
Coal TPS	233456	307588	396968	539014
GT/CCP	58427	89945	106939	133947
Nuclear	10145	13952	23834	39539
Total	370929	501592	644488	862904
C. Sales	285615	386226	496256	664436

It is further assumed that T&D losses will remain more-or- less unchanged from the present day level of 23% of energy despatched from power stations. Table 2.3.2 also gives the total energy sales projections. It may be noted that these figures correspond only to billable sales -- the actual electricity consumption by consumers will be higher to the extent non-technical or commercial losses occur [10]. These "billable" sales are projected to increase from 168,269 GWh in 1989/90 to 664,436 GWh by 2009/10, at the rate of 7.1% per annum.

Fossil-fuel requirements for power generation are also expected to increase (Table 2.3.3). The underlying assumptions are that

(a) 0.65 kg of coal (INCC) and 15 ml of oil (largely fuel oil) will be required per kWh of gross generation obtained from thermal power station (TPS) units, and

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[10] In India, non technical losses are estimated at over 10% of energy sent out from power stations. In the BAU strategy, this level of non-technical losses is assumed to persist through to 2009/10.

(b) about 0 2815 cu m of natural gas will be required (on an average) per kWh of gross generation obtained from GTs and CCPs.[11]

Table 2.3.3. Fuel requirements for power generation

	1994/95	1999/00	2004/05	2009/10
Coal (MT)	168.6	222.1	286 7	389.3
Fuel Oil (000' tonnes)	3793 7	4998.3	6450 7	8759 0
Gas (mcm)	16868 9	25968.6	30875.2	38672.9

Although a detailed analysis of T & D system expansion is necessary, from an engineering point of view alone it is possible to estimate the total lengths of transmission and distribution lines and substation capacities required (Table 2.3 4) The following assumptions are made on the basis of past data

(a) 2 5 km of transmission lines ($\geq$66 kV) per MW of installed capacity,

(b) 16 0 km of sub-transmission and distribution lines ($\leq$ 33 kV) per MW of installed capacity,

(c) 1 9 MVA of substation capacity for transmission system ($\geq$ 66 kV) per MW of installed capacity,

(e) 1 8 MVA of substation capacity for subtransmission and distribution system ($\leq$ 33 kV) per MW of installed capacity

Table 2.3.4 T & D system expansion

	1994/95	1999/00	2004/05	2009/10
>=66 kV (ckt-km)	62864	74386	86191	129420
<=33 kV (ckt-km)	409095	487320	566680	847886
>=66 kV s/s (MVA)	47776	56534	65505	98359
<=33 KV s/s (MVA)	46023	54824	63752	95387

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[11] Although the thermal efficiency of GTs is about 28 30% and that of CCPs (as envisaged at present - there are no CCPs in operation as yet) is higher at about 43% an average figure of 35% efficiency in generation is taken This obviously indicates that both GT and CCP capacity will be in operation in the coming years

CHAPTER 3
Renewable energy supply options

3.1 Background

Greater use of renewable sources of energy, efficient use of energy and increasing the forest cover in India have compelling reasons. Sustainable energy systems demand the ultimate reliance on renewable forms of energy [1] Different technologies based on renewable sources of energy, often less harsh on the environment, have been developed and/or deployed in developing countries in attempting to build sustainable energy systems which reduce environmental concerns. Much more, however, remains to be done. As pointed out by Grubb (1990), the speed and the impact of the transition to energy systems relying more on renewable sources will depend largely upon the political and financial commitment made and the policies adopted over the next decade or so for this transition

A dispassionate look at the renewable energy programme in India to date would indicate that there are some technologies (namely, grid connected wind turbines, small hydro power generation, solar photovoltaics, solar cookers and hot water systems) which have achieved a level of reliability and user acceptance. Government support in terms of subsidy may be required only to correct the distortions in the pricing (except in the case of solar photovoltaics where the high costs requires justification from social benefits that would accrue from its use) of conventional energy sources [2] There are others (such as gasifiers, biomass based stirling engines, and windmills) which are nearing the commercialization stage and government support is required for demonstration and further work on enhancing reliability and/or further technology development Then, there are a group of technologies somewhere in between the two. These technologies have achieved a fair degree of maturity but their diffusion suffers due to the manner in which they are promoted. Biogas and improved cookstoves are some technologies that fall in this category where, among other things, the technology has not evolved due to very little user feedback to the technology development effort.[3] Finally, there are several technologies which still seem to require an extensive R&D effort and/or substantial cost reduction.

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[1] See Jackson (1991) for a review of the role and the relevance of renewables for a sustainable energy system and Sorenson (1991) for a brief history of technologies based on renewable energy sources

[2] In the case of grid connected wind turbines, substantial commitment may be desirable from the Government for (a) changes in policy and existing law relating to the generation and the sale of power, and (b) initiating and encouraging the indigenisation of the technology in view of the projected potential (of the order of 20,000-45,000 MW for this technology in India and the existence of the industrial infrastructure to achieve self-reliance (see Hossain 1991 for details) The former is also important for small hydro development We examine these aspects in more detail in Chapter 7

Clearly, unambiguous statements of the constraints and the strengths associated with different renewable technologies is called for in order to regain credibility for these technologies. Substantial efforts need to be devoted to a serious assessment of what current technology is able to achieve and to arrive at a realistic estimate of the potential for these technologies within the context of the overall energy system. This chapter is an attempt in this direction.

We first briefly review the status of the renewable energy programme in India. The purpose is to provide an overview of the status of the technology in the country and to provide a backdrop against which strategies for a more effective deployment (presented in Chapter 7) can be discussed.

3.2 Windfarm power generation[4]

Amongst renewable technologies, windfarms appear the most feasible and cost effective for supplementing the conventional means of power generation on a large scale. As of late 1991, 37.5 MW of grid connected windfarms were operational in India and the performance of these windfarms has established the technoeconomic viability of this option.

Review of experience with windpower generation

The operation of windfarms over the last 4 years shows an average availability of about 98% and the Capacity Utilization Factor (CUF)[5] has been found to be as high as 30% at some locations (see Table 3.2.1). The operation of windfarms since 1986 has, apart from demonstrating the technical feasibility, has provided rich and unique experience in operating wind farms with Indian grid condition (fairly unstable) in tropical climate. Measures for improving grid conditions leading to improvement in the wind electric generation have been identified. The response of some organizations (particularly Tamil Nadu Electricity Board[6] and the Gujarat Energy Development Agency[7]) to the technical, managerial, and logistic problems posed by windfarm installation has been commendable

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[3] In fact, this is true for all renewable energy devices which have use at the household level such as solar cookers, solar hot water systems. In the case of biogas and improved cookstoves, the effect of neglecting the importance of user feedback has been particularly severe.

[4] This section is largely based on the work of Jami Hossain.

[5] The capacity utilization factor (CUF) is defined as
CUF = [Annual Energy Generated]/[Rated Power X 8760])

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[6] TNEB has established a separate *wind energy wing* responsible for wind power development activities The wind energy wing has not only been installing and maintaining windfarms, but is also involved in identifying new sites, designing grid interfaces prepares expansion plans' reports and offers consultancy on wind power development

In addition to this, TNEB has been at the forefront of implementing innovative measures such as energy banking and the wheeling of energy (with a nominal 2% of the generated electricity as the wheeling charges) for private organizations' industry with installed windfarms and has resulted in encouraging response within the state Till 1991 end installed captive wind electric capacity in the state was 4.75 MW

[7] The major achievement of GEDA has been the identifying of measures for improving the grid conditions and getting these implemented by the electricity authorities leading to significant improvement in the performance of the windfarms and grid conditions

Table 3.1.1. Performance of selected windfarms in India.

			Capacity Utilisation Factor			
	Capacity (kW)	1987	1988	1989	1990	Average
Mandvi I	550	17.78	15.83	13.55	14.42	15.39
Mandvi II	500				12.00	12.00
Tutucorin I	550	16.60	13.53	13.66	14.41	14.55
Tutucorin II	550	16.20	14.30	15.29	16.18	15.49
Okha	550	17.21	11.94	9.73	13.29	13.06
Puri I	550	9.30	5.16	1.24		5.20
Puri II	550				4.15	4.15
Deogarh I	550	10.86	9.70	8.28	7.30	9.03
Deogarh II	550			5.65	7.28	6.46
Kayathar IA	1350			19.33	22.27	20.28
Kayathar IB	1200				23.50	23.50
Kayathar II	6000				24.81	24.81
Tirumalla	550				9.70	9.70
Okhamadhi	1800				12.00	12.00
Kheda	500				10.08	10.08
Lamba	10000				9.18	9.18
Mupandal	4000				29.83	29.83
Sultanpet	90		15.39	13.07	13.37	13.94
Puliyankulam	90		11.92	10.9	13.48	12.10

Since 1985, the Ministry of Non-conventional Energy Sources (MoNES), previously Department of Non-conventional Energy Sources (DNES) has carried out an extensive wind monitoring and mapping programme to identify better sites and to assess the resource potential.[8] The programme has been implemented in a very systematic manner and the compiled data has been analyzed and is being published in the form of books (one such compilation is Mani 1990) with the ultimate objective of preparing a wind atlas for the country The wind mapping programme was largely responsible for the identification of some excellent windfarms sites such as Mupandal, Kayathar, Lamba and Dhank in Tamil Nadu and Gujarat and has identified several potentially windy regions indicating a fairly large potential for wind energy utilization. The exact potential[9] for windfarms in India, however, is yet to be properly assessed.

Potential for windfarm power generation

Estimates of the MoNES place the ultimate wind-energy potential at 20,000 MW. Another study (Hossain 1991) estimated the potential on the basis of land availability only along the coastal regions having adequate wind resource to be of the order of 50,000 MW. If offshore and inland installations are also considered, the figure should be much higher.

The MoNES has initiated a wind monitoring programme with 10 m and 20 m masts in the states of Tamil Nadu, Orissa, Maharashtra and Gujarat (Mani 1990). Mani and Mooley (1983) had earlier compiled and published windspeed data from 343 meteorological stations in the country. We use both, the data generated by the wind monitoring programme and the meteorological data to make rough estimates of the potential for windfarm power generation [10]

With existing technology, wind energy power generation in the regions with windspeeds of 5 m/s or greater at the hub height of the turbines (25 m) is considered to be economically viable Table 3.2 2 lists sites with mean annual windspeeds (extrapolated to the hub height of 25 m) exceeding 4 m/s. The sites have been categorized according to the windspeed range viz., 4-5 m/s, 5-6 m/s and those with windspeeds exceeding 6 m/s

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[8] Even prior to this activity the MoNES initiated the compilation and the publication of windspeed data from meteorological wind monitoring stations (see Mani and Mooley 1983)

[9] The term "potential" can be used in several contexts It can refer to the capacity that can be ultimately installed at a certain point of time in future without any consideration of other factors For wind energy utilization the potential, *in this sense*, would be very large with the land availability determining the upper bound The *realizable* potential of windfarms is, however, limited by the nature and capacity of the existing generating system in addition to the physical land availability Here "potential" refers to the *realizable potential* for windfarms, keeping in view the land availability, wind resource and the expected generating capacity in future

[10] Though there is some skepticism regarding the usefulness of the meteorological data for wind energy calculations as these observations were made for meteorological purposes at varying heights and the anemometers were not sited from the point of view of wind resource assessment A combination of the data generated by wind monitoring programme and the meteorological data, however, does give a fair idea of the wind regimes in the country

The stations listed in Table 3.2.2 are located in the states of Karnataka, Madhya Pradesh, Gujarat, Tamil Nadu, Orissa, Maharashtra, Rajasthan, Goa and West Bengal

With the available wasteland as the only constraint, the level of potential at some of the best sites exceeds 172,441 MW (Table 3.2.3). This may be deemed as the "ultimate" potential of windfarms and, as the cost of generation is below Rs 3/kWh Of all the districts listed, Kachch, in the western state of Gujarat, accounts for nearly half of the potential and this is more because of large amount of wastelands than high wind energy resource.

Table 3.2.3 Ultimate potential of windfarms in selected districts with highest wind resource

District	Waste-land sqkm	Windfarm potential MW	Wind-speed m/s	Specific output at 25m kWh/kW/yr	Cost of electricity of WEG Rs/kWh	Tot Gen in life GWH
Kachch	38640	82998	5.25	1607	2.87	2668123
Jamnagar	7280	15637	5.68	1945	2.37	608281
Rajkot	3300	7088	5.57	1858	2.48	263340
Junagad	3080	6615	5.58	1866	2.47	246814
Bhavnagar	4400	9451	5.35	1685	2.74	318466
Ratnagiri	5980	12845	5.22	1584	2.91	406994
Puri	2700	5799	5.15	1531	3.01	177528
Baleshwar	1440	3098	5.04	1447	3.19	89682
Ramanathapuram	5850	12565	5.16	1538	3.00	386575
Coimbatore	2220	4768	5.38	1708	2.70	162895
Tirunelvelli	4950	10632	5.84	2073	2.23	440770
Kanyakumari	440	945	6.43	2546	1.81	48126
Total	172441					

There is, however, significant difference between the "ultimate" and the realizable potential of wind energy and this is largely due to the highly intermittent nature of wind as an energy source The fluctuating nature can have serious implications for the stability of the grid depending on level of contribution that this source makes to the total capacity (henceforth referred to the "penetration" level) on the grid. In general, the penetration level (indicative of the realizable potential that windfarms can make to the regional grid) depends on the operating constraints/ characteristics of the power system in question. Studies indicate that the optimal penetration levels may vary 5% to 50% (see Hossain 1992 for a detailed discussion) depending on the generation mix on the grid. In a simulation study for Tamil Nadu, penetration of windfarms as high as 35% was found to be technically acceptable but the optimal penetration level was found to be of the order of 25% (Hossain et al. 1991) The growth in the capacity of the various regional grids (discussed in Chapter 2), i.e., eastern, northern, southern, western, etc.[11] are based on the current estimates of the financial allocation to the power sector and the stage of implementation of the different projects Using the penetration level of 25% (with the capacity at the end of the 9th plan), the realizable potential of windfarms, shown in Table 3.2.4, total to over 29,000 MW by the end of the 9th plan and nearly 39,000 MW by 10th Plan end Also included in Table 3.2.4 are the long run marginal costs (LRMC) of power generation for the different regional grids and other assumption used for calculating the costs associated with windfarm installations.[12] The LRMC estimates are, like the estimates of the windfarm potential, based on the specific capacity expansion plans of the regional grids

Table 3.2.4 Grid capacity and potential for windfarms on the basis of 25% penetration level (in MW)

	LRMC Rs/kWh	Installed capacity End of 9th pln	10th pln	Maximum windfarm potential End of 9th pln	10th pln
East	1.59	19381	25933	4845	6483
North	1.63	38397	49645	9599	12411
North east	1.62				
South	1.46	25780	38928	6445	9732
West	1.52	33510	40670	8378	10168
All India	1.56	117068	155176	29267	38794

Source· Cost (LMRC) of electricity (ref ADB study, draft final report, p 166)

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[11] Of the states with significant potential for windfarm generation, the states Madhya Pradesh, Maharashtra Goa, and Gujarat fall in the western region states Tamil Nadu and Karnataka in southern region, Orissa in the eastern region and Rajasthan in the northern region

[12] The cost of power generation for windfarms installations are the life cycle costs based on the levelized annual cost (LAC) As is well documented, LAC appears to be the appropriate method to calculate the costs of generation considering the high capital and low operating costs of most RETs

Though the estimated potential is immense and the feasibility of windfarm power generation has been amply demonstrated by the performance of the existing windfarms in the country, the actual level of deployment of the technology in the country will be determined by the financial resources available for wind power development To a lesser extent, subject to the availability of the requisite finances being available, it would be determined by the maturing of the industry involved in the manufacture of wind generation equipment, particularly in the context of the Eighth Plan emphasis of relying on indigenously manufactured equipment. Needless to add, these are not the only constraints. These will be discussed subsequently along with strategies for a faster development of wind power generation

Financial allocations for wind power generation

The Eighth (1992-97) Plan allocation of Rs 90 crores for the wind energy programme (Planning Commission 1992) is definitely incommensurate with the potential of wind power generation.

Wind power manufacturing industry

The wind power generation programme was initiated in 1985/86 and, initially a large number of international and Indian suppliers (collaborating with international manufacturers) were encouraged to participate. Some major industrial groups with in-house R&D capability made collaborative arrangements with reputed international suppliers for the supply wind electric generators (WEG). List of the major organizations and their international collaborators are as follows

Indian company	Foreign collaborating company
Best and Crompton Ltd	Windmatic, Denmark
Bharat Heavy Electrical (BHEL)	Nordex, Denmark
Hindustan Brown Boveri	Nordtank, Denmark
J K Synthetics	Wincon, Denmark, Polenko, Holland
Natural Energy Processing Co (NEPC)	Micon, Denmark
RRB Consultants and Engineers (P) Ltd	Vestas, Denmark
Thermax (P) Ltd	Bonus, Denmark
Western India Erectors Ltd	Micon, Denmark (previously)

Of these, only three companies, i.e , RRB Consultants, NEPC and BHEL are still active in the windpower industry. JK Synthetics, which installed the first grid connected WEG in India with the Gujarat Energy Development Agency at Veraval and which was active in windpower development for six years has stopped activities in the area Others are virtually inactive [13] Part of the reason may be the total control of the MoNES on the windpower programme relying largely on DANIDA funding (which has resulted in capacity addition of 20 MW).[14]

Among the three active companies, BHEL has a strong engineering group and the requisite infrastructure for technology development. Under a MoNES sponsored project, BHEL has installed indigenously developed wind turbines.[15] RRB and NEPC are very small compared to BHEL but they have been able to effectively provide installation, commissioning and maintenance services. Both RRB and NEPC were believed to be considering production of wind turbines with partially imported components late last year.

The introduction of a 40% import duty on imported wind turbines from July 1991 is expected to further encourage local production of machines.

3.3 Small hydel power generation[16]

Small/micro/mini hydel is another technology with enormous potential. Till the beginning of 1992 only 83 MW (spread over 113 projects) of the total potential of 5,000 MW in India had been reportedly harnessed.[17] In order to provide a sharper focus to this renewable source of energy the subject of small hydel development up to 3 MW capacity was decided to be transferred to the MoNES from the Department of Power in February 1989. MoNES had earlier initiated some small demonstration projects in the high, medium, and low head categories with the ultimate objective of making them models of their types of heads and flows in design, engineering, and equipment selection. Though additional sites have been identified (see Tables 3.3.1 and 3.3.2), it is difficult to estimate the likely penetration of this technology beyond 2000 AD. Obviously, a lot depends on the experience with the programme in the next decade.

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[13] There is a feeling among some in the windpower industry that in the initial years the major industrial groups with in house capabilities and resources, were not encouraged to participate in indigenous development As a result this technology did not utilize the best technical expertise and infrastructure in the country A reversal of this by finding ways of again involving the industrial groups which had initially shown interest (such as Hindustan Brown Boveri and JK Synthetics) in participating in the indigenisation activities would strengthen the wind power development in India

[14] Of late, largely due to innovative energy banking scheme introduced by the TNEB, fiscal incentives by the government such as allowing 100% depreciation to deducted from the income tax and the power shortage in the Tamil Nadu, interest is being shown by industry to use wind generators for captive power generation The installed capacity of such generators is reported at 4 75 MW in 11 companies in Tamil Nadu

[15] Several BHEL machines are currently installed in different parts of the country Sixteen of the turbines are of the 55 kW, two 200 kW machines are at Kayathar and Lamba and a 1 5 MW turbine has been manufactured for testing at Vijaydurg

[16] This section is largely based on the work of Chandra Shekhar Sinha Data and other information provided by Arun Kumar, MoNES is gratefully acknowledged

Table 3.3.1: Summary of the potential of small hydel at identified sites.

	Capacity MW	Total cost crore Rs	Installed cost Rs/kW
Mini hydel	980.46	2117.20	21594
Canal drop	148.71	332.93	22388
Total	1129.17	2450.13	21699

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[17] There is some confusion regarding the exact installation and the projects in the status of "work in progress". We suspect that this was caused by the transfer of the responsibility for small-hydro projects (of capacity lower than 3 MW) from the Department of Power to the MoNES in 1989. In comparison to the figure presented here, the MoNES lists the capacity of operating schemes at 4.55 MW while the total capacity of the schemes where work is in progress is listed at 11.2 MW with a total of over 35 MW in all projects (see Table 3.3.3 for details)

Table 3.3.2 Proposed and ongoing Mini hydel schemes

	DPR NOT ready		DPR ready		Targeted		Operational	
	Capacity MW	Cost crore Rs	Capacity MW	Cost crore Rs	Capacity MW	Cost crore Rs	Capacity MW	Cost crore Rs
Bihar	25 10	64 70	1 00	2 50				
Orissa	14 60	29 90	0 01	0 30			0 04	0 80
West Bengal	38 20	70 50						
Sub-total	77 90	165 10	1 01	2 80	0 00	0 00	0 04	0 80
Haryana			24 10	52 30	0 40	1 30		
Himachal Pradesh	8 30	12 40	0 50	1 30				
Jammu & Kashmir	63 00	103 90	23 70	62 30	7 60	28 80		
Punjab	41 90	124 20	29 30	60 90				
Uttar Pradesh	99 00	208 60	4 40	11 60	16 70	35 70	8 60	20 90
Sub-total	212 20	449 10	57 90	136 10	24 30	64 50	8 60	20 90
Assam	9 60	15 60	6 00	7 80				
Manipur	7 00	13 00						
Meghalaya	5 20	13 80						
Nagaland	0 50	1 00	7 80	18 00	0 80	2 30	2 50	5 80
Sikkim	9 10	17 00						
Tripura	4 40	10 10						
Arunachal Pradesh	40 30	76 00			6 80	14 40	14 10	27 80
Mizoram	1 50	11 10						
Sub-total	77 60	157 60	13 80	25 80	7 60	16 70	16 60	33 60
Andhra Pradesh	30 30	71 80	12 60	28 30				
Karnataka	6 90	17 60	17 00	32 00	24 10	64 10		
Kerala	112 00	247 50	9 70	25 20	10 00	12 90		
Tamil Nadu	77 40	125 50	7 90	10 30	4 80	9 90		
A & N Islands	3 00	4 50						
Sub-total	229 60	466 90	47 20	95 80	38 90	86 90	0 00	0 00
Gujarat	8 30	25 30	18 51	46 00	2 00	6 60		
Madhya Pradesh	27 50	60 30	9 70	21 80	3 80	9 60		
Maharashtra	61 00	142 10						
Rajasthan	0 80	2 00	8 60	21 70	1 00	3 30		
Goa, Daman and Diu	1 50	2 30						
Sub-total	99 10	232 00	36 81	89 50	6 80	19 50	0 00	0 00
TOTALS	696 40	1470 70	180 82	402 30	78 00	188 90	25 24	55 30

Table 3.3.2: Proposed small hydel schemes on canal falls. (cont ..)

	Capacity MW	Cost crore Rs	Number of sites
EASTERN			
Bihar	1 00	2.50	1
Orissa	0.01	0.03	1
Sub-total	1.01	2.53	2
NORTHERN			
Haryana	24.00	52.30	20
Punjab	29.30	60.90	21
Sub-total	53 30	113.20	41
SOUTHERN			
Andhra Pradesh	40.60	96.30	8
Karnataka	17 00	32 00	8
Kerala	9 70	25 20	6
Tamil Nadu	2.40	3.40	2
Sub-total	69.70	156.90	24
WESTERN			
Gujarat	15.00	38.50	13
Madhya Pradesh	9.70	21.80	12
Sub-total	24.70	60.30	25
TOTALS	148 71	332 93	92

Source. DNES, 1989, Mini Hydro Power proposed Eighth Plan implementation programme, Vol 1, pp.25-26

Level of funding

The Working Group for the 8th Plan for MoNES recommended had a target of over 831 MW for small hydel and a budget of Rs 824 6 crores for the MoNES for small hydel development In view of the problems with financial resources, the targets and outlays recommended by the Working Group were revised downward and the revised request was for sanction of Rs 300 crores, which, with participation of state governments, private entrepreneurs, financial institutions, etc. was expected to attract an additional investment of Rs 430 crores taking the total inflow to around Rs. 730 crores by 1997 for small hydro development

The Eighth Plan commitment for the small hydel sector, however, is Rs 100 crores (Planning Commission 1992) The World Bank is expected to provide a loan of US$ 70 million (Rs 210 crores, @ Rs 30/US$ in 1992 Rs) for developing 110 MW through IREDA. The Global Environment Facility (GEF), being administered through the UNDP and the World Bank, has, in principle, agreed to finance the development of small hydel projects in the hilly regions of the country by investing US$ 7.52 million (Rs 22 6 crores) (see Singh 1992 and Kumar 1992). The total likely level of funds available for small hydro development is therefore likely to be about Rs 332 crores in the Eighth Plan period. With participation of state governments, private entrepreneurs, and other financial institutions, etc., additional investment of Rs 100-150 crores may be possible, taking the total inflow to around Rs 425-480 crores by 1997 for small hydro development. The current MoNES commitment (see Table 3.3 3) for the small hydro development, reflected by the sanctioned schemes (including schemes where the work is in progress) is about Rs 24 8 crores (computed from MoNES. Urja Bharti: August 1992).

Table 3.3.3 Current status of small hydro in India

	State	Unit size kW	Total capacity kW	Outlay Rs lakhs	MoNES Share Rs lakhs	Commissioning date
Chettupetta	Andhra Pradesh	500	1000	176 9	69	
Kakroi	Haryana	1000	3000	141	119	
Jubbal	Himanchal Pradesh	150	150	30 64	30 64	
Manali	Himachal Pradesh	100	200	57 56	57 56	
Bilkot	Uttar Pradesh	50	50	40	15 83	
Khet	Uttar Pradesh	50	100	49 48	21	
Naini	Uttar Pradesh	50	50	39 96	13 52	
Sriram sagar	Andhra Pradesh	500	1000	225	110	31/9/92
Sriram sagar	Andhra Pradesh	500	1000	225	110	31/9 92
Sriram sagar	Andhra Pradesh	500	1000	225	110	28/2/92

Bhim Garh	Madhya Pradesh	1200	2400	559.95	2.06*	31/3/93
Chambal	Madhya Pradesh	600	1800	668.27	26.1*	31/3/93
Chargaon Jatalpur	Madhya Pradesh	800	800	262.98	1.15*	31/3/93
Korba	Madhya Pradesh	800	800	236.88		October 1992
Satpura	Madhya Pradesh	500	1000	247.5	118.8	31/3/93
Tilwara	Madhya Pradesh	250	250	106.31		31/3/93
Barbora	Orissa	325	650	193	96.58	31/3/93
Kendupatana	Orissa	250	500	180	90	31/10/92
Kipti (Twang district)	Arunachal Pradesh	1500	3000	540	270	
Laromoba (West Siang)	Arunachal Pradesh	1000	2000	460	230	
Mukto (Twang district)	Arunachal Pradesh	1500	3000	540	270	
Siddip (East Siang)	Arunachal Pradesh	1000	3000	580	290	
Sippit (East Siang)	Arunachal Pradesh	1000	2000	460	230	
Andhari Bangi	Orissa	325	325	77.18	19.3	31/4/93
Badnala	Orissa	325	650	140.3	35.6	31/12/92
Biribati	Orissa	325	650	180	45	31/12/92
Harbhangi	Orissa	1000	1000	366.1	91.53	30/6/93
Potteru Stage I	Orissa	3000	3000	407.09	101.77	31/12/93
Potteru Stage II	Orissa	3000	3000	420.09	105.22	28/2/94
Bagar	Uttar Pradesh	50	50	22.5	11.25	31/10/93
Karmi	Uttar Pradesh	50	50	22	11	31/10/93
Lathi	Uttar Pradesh	50	100	40	20	31/10/93
Sangad	Uttar Pradesh	50	50	21.2	10.6	31/10/93
Bahadrabad	Uttar Pradesh	125	250	63.47	33.47	
Operating schemes			4550	536	327	
Work in progress schemes			11200	3130	665	
Total schemes			37875	8005	2766	

Source Urja Bharti (August 1992), MoNES, page 42

Experience with small hydro in India

To date however, the experience with small hydro development India has not been very encouraging It is common to encounter doubts among those involved with the power sector regarding the viability of the small hydel projects. These doubts persist because the experience with pilot irrigation based small hydel schemes [18] During the Seventh (1985-90) Plan, SEBs in the South initiated work on 16 projects Till late 1990, only six of these had been completed[19]. Three main reasons have been forwarded for the poor performance of these projects (ESMAP 1991). Firstly, the initial batch of schemes were conceived, designed and executed as scaled down versions of large conventional hydro installations Consequently, there are numerous redundancies in the design for key features such as the layout for the civil works, the facilities incorporated into the powerhouse structures, the selection for turbine-generator equipment, and the specification of the electrical switching and protection systems Second, due to the use of relatively complex layout for the schemes, the gestation time to construct and commission the schemes the schemes had been high. For example, majority of the pilot schemes in the southern region has taken over four years to commission As a result of the slow pace of implementing the construction work, there has been a significant escalation of the costs [20] Thirdly, the viability of the pilot schemes were undermined by the use of unnecessarily large number of technical staff to operate and maintain the pilot schemes It is expected that with the experience of the pilot schemes would result in qualitative improvement of the programme. In fact, detailed reexamination of the project reports in the five states of Andhra Pradesh, Karnataka, Kerala, Punjab, and Tamil Nadu (totalling to over 130 MW of proposed capacity) has been completed The state-wise summary of the potential based on other identified sites are given below (Table 3 3 4)

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[18] The dismissive attitude towards small hydro among those responsible for power sector development is also due to the emphasis of the Government to add large installed capacities within extremely short time interval the installed capacity increased from 2300 MW in 1950 51 to 74400 MW (see MoF 1992) in 1990'91 implying capacity addition of over 1800 MW every year

[19] As indicated earlier, the responsibility for small hydro development is now with the NoNES Since 1989, the progress made by MoNES has been commensurable and it is hoped that by the Eighth Plan and substantial progress will have resulted in small hydro development

[20] In Tamil Nadu such delays resulted in cost escalations in all the three projects The cost of the Lower Bhavani Scheme, in the 5 years of construction work, rose from Rs 20 7 to 24 1 crores For the Vaigai the escalations were from Rs 14 to 16 2 crores

Table 3.3.4. State-wise summary of small hydel projects with reexamined DPR.

	No of units	Total Capacity MW	crore Rs Total cost	Energy output GWh/year
Andhra Pradesh	36	58 10	78 07	287 40
Karnataka	38	33.00	64.15	147.31
Kerala	24	16.90	40.18	62 51
Punjab	20	8.20	35 77	27.38
Tamil Nadu	27	13.15	40.22	48.62
TOTAL	145	129 40	258 39	573 22

ESMAP 1991 22 for capacity and energy production, ESMAP 1991.36 for costs

The state-wise summaries were presented in Tables 3 3 1 and 3.3.2 It must be emphasized that the presented estimates are only for identified sites and reflect possible installations in the next 5-10 years depending on the priority attached to developing the potential in this sector.

Expecting difficulties with financial allocation from the Government, the MoNES has determined and formulated priorities for the various components of the small hydro development and the *interse* priority allocated to them. For the small hydro development programme, these have been tentatively delineated as follows and therefore the proposed budgetary support could be allocated as shown in Table 3 3.5.

Financial incentives for small hydro development

All small hydro projects in grid connected areas are now eligible for 25% capital subsidy on the "reasonable" cost of civil and electro mechanical expenses For non-grid connected areas (defined as areas where the grid be more than 1 km away) the subsidy can be upto 50% Based on a decision of Commission on Additional Sources of Energy (CASE) taken on 26 January 1992, these subsidies can be availed of by any investing organization, public, joint, cooperative, private or voluntary

MoNES has also announced (on 10 May 1991) a scheme of sharing 50% of the costs incurred on DPR (Detailed project report) preparation, subject to a limit of Rs 10,000/- plus Rs 100/- per kw of investigated capacity.[21] The scheme is open to all organizations, including those from the private sector.[22]

Many renewable energy equipment, such as those running on solar, wind, etc , Government of India has given a number of additional incentives which include permission to depreciate 100% of the capital cost in the first year of purchase under the Income Tax Act, import without any license and generally with duties ranging from 0 to 40%, total exemption from Central Excise and Sales Taxes and now concessional finances from many financial institutions *These, however, are not available for small hydro sector*

Cost of small hydro development

The costs of constructed/ committed small hydro projects listed in Table 3 3.3 vary widely the minimum cost id Rs 4700/kW and the maximum is Rs 80000/kW The average cost for the listed projects is about Rs 27950/kW As discussed, the estimates of the cost are based on the limited experience in India in the design and commissioning of small hydro installations It is therefore important to examine the costs of projects where considerable effort have been made to optimize the design (to increase the energy output) and, simultaneously, reduce design complexities to lower the costs ESMAP (1991) has summarized the cost and performance data for 145 such small hydel units in five states totalling about 130 MW a the approximate capital requirement of Rs 260 crores (late 1991 costs, incorporating the devaluation of the Rupee), giving the average cost of Rs 20000/kW [23]

Manufacturing infrastructure

Significant indigenisation has been achieved in the manufacture of small hydel equipment Technology transfer tie-ups with 9 prominent manufacturers of equipment of the world These are as follows (Kumar 1992)

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[21] Travel allowance for a maximum of 3 persons for two site visits are in addition to this fee

[22] The World Bank has recently (in 1992) added a condition that the schemes for World Bank financing should be mainly implemented by private developers Though felt to be a step having resulted in slowing the implementation programme to some extent, the long term effect my be beneficial to the small hydro development For instance due to this condition the MoNES has state governments to lay down policy and guidelines to enable private sector generation

[23] As discussed, the identified sites amount to about 1160 MW Estimates place the potential of small hydro at 5000 MW in the country based on the survey of REC in the mid-eighties

Sl. No.	Name of Indian Firm	Foreign collaborator country
1.	M/s Jyoti Ltd	M/s Escher-Syss, Switzerland - now expired
2.	M/s Best & Crompton Engineering	M/s DUMONT Neyrpic, France
3	Boving Fouress Pvt Ltd	M/s Boving & Co , UK
4.	Flovel Ltd	M/s Tempella, Finland
5.	Larsen & Toubro Ltd	M/s Voith, West Germany
6.	Punjab Power Generation Machines Ltd	M/s Voest-Alpine, Austria
7.	Steel Industrial Kerala Ltd	M/s Koessler, Austria
8	Bharat Heavy Electricals Ltd	M/s Neyrpic, France - now expired
9.	Triveni Engineering Works Ltd	M/s Esac Energie, France

Typically, these foreign collaborations had to follow rigorously laid down phased manufacturing programmes in which the import content was to be reduced from an average of 30% in the first year of manufacture to less than 10% in the 5th year of manufacture At the present level of production, however, it is found that the manufacturers are still required to import items such as Runners, Governors, Runner Servomotors, Self Lubricating Bearings, Spherical Bushes, Shaft Seals, Sliding Pads, Gear Boxes, Flexible Couplings, Frictional Couplings, Shrink Disks, Turbine Bearings, Stainless Steel Plates, Compact Rod Seals, etc Most of these imports, however, have to be resorted to under specific import licenses and subjected to relevant import duties

Table 3.3.5 Proposed budgetary requirements for micro hydel sector

	Priority Sector	allocation (%)	*Interse of Funds* (Rs in crores	(MW	Capacity (Financial Physical) I	II	III	Phasing (1992 97) IV	V
I	Repair modification of existing small hydel projects leading to cost effective increases in capacity	10	30	60	1.0 (2)	3.0 (6)	5.0 (10)	9.0 (18)	12.0 crore (24) (MW)
II	Development improvement of traditional watermills with a view to make electricity generation possible at a village entrepreneurs level	5	15	10	0.75 (0.5)	1.5 (1)	2.25 (1.5)	3.0 (2)	7.5 crore (5) (MW)
III	Small hydel potential of perennial steams in hill areas largely decentralized	30	90	36	7.5 (3)	12.5 (5)	17.5 (7)	22.5 (9)	30.0 crore (12) (MW)
IV	Small hydel potential of irrigation canal falls and dams largely grid connected	50	150	150	10.0 (10)	20.0 (20)	30.0 (30)	40.0 (40)	50.0 crore (50) (MW)
V	R & D manpower development data bank activities etc	5	15		0.5	1.5	2.5	4.5	6.0 crore
	Grand total		300	256	19.75 (15.5)	38.5 (32)	57.25 (48.5)	79.0 (69)	105.5 crore (91) (MW)

I Priority sites are expected to have the shortest gestation periods and give the most effective value for money because no new site surveys or environmental clearance are required At the rate of Rs 1 crore per MW with MoNES share limited to Rs 0.5 crore per MW the allocations proposed can thus lead to the creation of 60 MW capacity

II *Priority sites* will be requiring very little financial outlays but will lead to tremendous multiplier effects in the economy of far flung hills villages At the rate of Rs 15,000 per *gherat* (watermill) with MoNES share limited to Rs 5,000 per *gharat* the outlays proposed can easily lead to the upgradation of 10,000 *gharats* and also almost 10 000 kW of installed capacity apart from providing for training demonstration etc

III *Priority sites* are expected to serve remote hills and mostly unelectrified areas with setting up of local grids even though their implementation may be more time consuming with higher installed costs per KW at Rs 5 crore per MW therefore with MoNES share on an average limited to Rs 2.5 crore per MW this could lead to the harnessing of some 36 MW of new capacity

IV *priority sites* will conserve hydro energy presently being dissipated away help in improving hydel thermal mix and above all help in meeting agricultural electricity loads in times when they will be required the most Because of better infrastructural support easier availability of credit from bodies like World Bank is more likely for these sites At Rs 3 crore per MW therefore with MoNES share limited to Rs 1 crore per MW through the interest subsidization route this sector can easily yield over 150 MW within the proposed outlay

Source Kumar 1992

Against this, items which have been indigenised to some extent and are no longer imported in any great quantities are: Wicket Gate Servos, Shrink Discs, Flexible Couplings, Frictional Couplings, Pumps, Hydraulic Power Plates, Cranes, Butterfly Valves, Spherical Valves, Compressors, Bulb Housing Domes, Seamless Pipes, Generators, Control Panels Gear Boxes, Transformers, Oil Circuit Breakers, etc The list of manufactures of turbines and generators for small hydel application along with some details of the specification are indicated in Table 3 3 6

Table 3.3.6. List of manufacturers

Manufacturer	Head range	Type of turbine	Type of generator	Rating in kW	Scope of supply
Beacon Neyrpic Madras	2-6	Siphon	N A	N A	Turbine
	6-30	Kaplan			
	10 200	Francis			
	100-1000	Pelton			
Bharat Heavy Electicals, Bangalore	3-16	S type tubular	Induction	1000	Turbine,
	150-500	V Pelton	Synchronous	above 1000	Generator
	4	Bulb			Gear box
	16-25	V Kaplan			Control panels
	45-180	H Francis			
Boving Fouress Bangalore	upto 30	Full Kaplan	Induction	1000	T+G Unit,
	upto 30	Semi Kaplan	Synchronous	above 1000	E+M equiptment
	20-300	Francis			for turnkey
	above 200	Pelton			execution
Crompton Greaves Bombay					
		NM	NA	NA	Generators
Cegelac India Noida U P		NM	NM	NM	Automation of
					small hydro plants
Flovel New Delhi	2-20	Tubular/Pit		NM	Turbine
	3-10	Francis Open Flume			Gearbox
	15-300	Francis			
	90-400	Pelton			
Jyoti Vadodra	2 25	Tubular	Induction	upto 50	Turbine
	2 5 30	Kaplan	Synchronous	all capacities	Generator
	45-180	Francis			Control panel
	50 200	Turgo impulse			BF valve
	100-400	Pelton			
Kirloskar Electric Delhi		NM	Induction	upto 100	Generator
			Synchronous	upto 1500	Control panel

Larsen & Tubro Calcutta	upto 3 18	Prop type Francis Open Flume	N/A	N A	Turbine
	5 25	S-turbine			
	26 200	Francis (spiral casing)			
	200-400	Pelton double jet			
NGEF limited Bangalore			Induction	upto 300	Generators
			Synchronous	55-1600	
Punjab Power Generating Machines, Chandigarh	3-25	Tubular	Induction	upto 3000	Turbine,
	5-200	Francis	Synchronous		Generators
	100-400	Pelton			Gearbox, E+M works
Steel Industrials Kerala, Ltd Thrissur	1-30	Kaplan	Induction	upto 1000	Turbine,
	10-300	Francis	Synchronous	upto 3000	Generator,
	80 & above	pelton		and above	Control panels and
	upto 100 kW	Cross-flow demo units			turnkey execution
Triveni Engineering New Delhi	1 8-5	Kaplan with Syphon intake	Induction	50-1500	Turbine
	5-8	Bulb	Synchronous	200-3000	Generator
	10 130	Francis			Control panels and
	5-15	Pressurised vertical			turnkey execution
		Kaplan			

Source MoNES Urja Bharti August 1992 43-44

3.4 Photovoltaic technology[24]

Rural electrification has been the largest government funded rural energy programme in India. Over the last four decades over 470,000 villages (corresponding to about 81% of the total villages) have been electrified. In the Eighth Plan period an additional 50,000 villages are to be electrified Interestingly, for the first time emphasis has been placed on electrification using decentralized, renewable technologies.

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[24] This section is largely based on the work of Akanksha Chaurey and Suneel K Deambi

Many of the unelectrified villages are inaccessible from the existing grid for geographical reasons, which may make extending the grid technically difficult. It may also be uneconomical to extend the grid to many remote rural areas due to low energy demand intensity and large distance through which the grid has to be extended results in high capital cost The Eighth Plan proposes to electrify 10,000 villages using technologies based on in renewable sources

PV systems can play an important role for remote areas where grid extension is difficult and financially unattractive for uses with substantial social benefits (such as health care, education, etc). At present, the largest economically viable application sector for the PV cells is telecommunications, though PV for rural lighting for education and vaccine refrigeration have significant benefits. As PV cell costs decrease and the operating costs of competitive energy options increase, the economic viability limits of the PV systems, especially for stand-alone applications, is expected to improve greatly. Furthermore, since the system level technology to mold the various sub-components into a viable source of power for different applications has reached maturity, and further improvement in the sub-components is likely to, simultaneously, lower the cost and increase the reliability of the system. Due to the high costs, however, careful consideration is required of the benefits. Often, much lower cost options may be available to provide the desired service.

The PV programme for the Eighth Plan has been allocated Rs 90 crores of the total of the Rs 857 crore renewable programme of the Government (Planning Commission 1992). In addition, there are indications that the PV programme in India would receive US $ 55 million (about Rs 165 crores) for market development from the Global Environment Facility for a five year period corresponding to the Eighth Plan period Considering the level of funding likely in the PV sector, it becomes important to review the status of the technology in the country and to examine the existing implementing strategy for the technology.

Brief history of the PV programme in India

The Department of Science & Technology (DST) initiated a national programme on terrestrial solar photovoltaics in 1975 under which an integrated approach was evolved for research, development, manufacture, deployment, demonstration and education and training with the active participation of national research laboratories, academic institutions and a public sector electronics company, Central Electronics Limited (CEL). Scientific research on solar cells and development of photovoltaic materials was entrusted to the R&D laboratories and academic institutions whereas product development was assigned to Central Electronics Limited (CEL) -- a public sector company During the period 1975 to 1981, various organizations like the Department of Science and Technology, Council of Scientific and Industrial Research and the Department of Electronics provided financial support for the terrestrial PV programme. Following the establishment of the DNES (now MoNES), the solar photovoltaic programme for terrestrial application is co-ordinated by the MoNES which is also the main funding organization supporting solar photovoltaic research and development activity.

Over the last decade the programme has made substantial progress and the total installed manufacturing capacity in the country is 5 75 MWp per year, while an addition of 2.75 MWp has been announced[25] In the remaining parts of this section we review the installation of PV based systems in the country, summarize the experience of the implementation programme (still referred to as a "demonstration" programme), review the PV manufacturing infrastructure and, finally, conclude with the constraints with promotion of the technology in India.

Believed to be the largest PV demonstration programme in the world, the installation of systems in India (Table 3 4 1 and 3 4 2) is impressive

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[25] Out of the total installed and added capacity, 3 MWp per annum by Suryavonics Limited, Hyderabad has a 100% export commitment

Table 3.4.1 Summary of PV programme in India

Villages with PV street lights	8050
Streetlighting systems	20000
Water pumping systems	1181
Community lighting and TV systems	938
Domestic lighting systems	5050
Power plants (kWp)	601.2
source: DNES: Conference of Ministers-in-charge of Non-conventional Energy Sources of State/Union Territories, February 1992.	

Table 3.4.2 Statewise achievement of **solar** photovoltaic systems

cumulative upto 31 12 91

State	Community lighting/TV sys	Water pumping system	Villages covered with street lights	SPV power plants
Andhra Pradesh	6	61	3140	2
Arunachal Pradesh	14	14	30	1
Assam		69	20	
Bihar	103	94	177	
Goa	4	2	4	2
Gujarat	51	98	374	1
Haryana	42	8	2	
Himachal Pradesh	9	10	160	
Jammu & Kashmir	3	3	13	
Karnataka	2	8	95	1
Kerala	11	6	93	1
Madhya Pradesh	64	93	400	3
Maharashtra	64	92	1306	5
Manipur		2	30	1
Meghalaya		25	25	
Mizoram	1	7	41	
Nagaland	3	15	38	4
Orissa	36	65	478	
Punjab	43	5	2	
Rajasthan	110	86	707	
Sikkim	3	2	28	
Tamil Nadu	18	31	173	5
Tripura	122	13	52	25
Uttar Pradesh	205	74	305	2

West Bengal	1	39	200	3
Union Territory				
A & N Island	12	24	149	
Chandigarh				
D & N Haveli			4	1
Delhi				
Daman & Diu	9	25	4	1
Lakshwadweep	2			
Pondicherry				
TOTAL	938	971	8050	58
MoNES total figure	938	1181	8050	59

Much of the rural PV installations have occurred as a direct result of the demonstration programs led by MoNES in association with the state nodal agencies, and to a lesser extent, the electricity boards and non-governmental organizations. Of the total PV installations, 30% were on a commercial, unsubsidised basis for telecommunications, signaling, defense and similar applications. The remaining rural demonstrations were primarily in domestic lighting, street lighting, water supply and community services

Duties and taxes

Imports of PV modules, components and systems are allowed on Open General License, but are subject to customs duties Silicon for cell manufacture is subject to 30% ad valorem and 5% auxiliary duty. Duty on modules is 60%. PV systems are charged a 75% ad valorem duty and a 5% auxiliary duty. No duty is charged on silver powder suspension or on silicon resin rubber used in module manufacture. Other items such as EVA, Tedlar, and toughened low iron glass are charged an ad valorem duty of 35% after obtaining a User Certificate from MoNES (without which the duty rate is 150%). No sales or excise duties are imposed on PV systems Imports of batteries, lamp fixtures, light bulbs, pumpsets, inverters and controllers are subject to 150% duty (see DNES 1991).

GoI also offers 100% rate of depreciation under the Income Tax Act for individuals and businesses investing in PV systems

PV systems financing

Currently, the costs of most PV systems are shared between MoNES and the state agencies MoNES pays for and arranges the procurement of modules directly from the PV manufacturer The state agency secures a contribution from the beneficiary, which together with the state contribution pays for the balance of systems and installation. The beneficiary contribution varies from state to state. It is usually only 10 to 25 percent of the total cost made in a lump sum. In the case of village power systems, however, each household pay a nominal amount which can at the most, only for the maintenance technician

PV manufacture infrastructure in India

The PV industry in India is relatively new as compared to the international industry The commercial production of solar cells and modules in India had started in 1983-84 in two public sector organizations, but the actual growth of the PV industry appears to have started only recently. Currently India has indigenously developed technology and production base from the stage of silicon material to the final PV system integration for crystalline silicon based PV devices. This industry consists of one silicon feedstock and wafer manufacturer (Metkem[26]), three solar cell manufacturers (Central Electronics Limited (CEL), Bharat Heavy Electrical Limited (BHEL) and Suryavonics Pvt Ltd [27]), six module manufacturers (Rajasthan Electronics and Instruments Limited (REIL), Renewable Energy Systems Pvt Ltd , Udhaya Semiconductor Pvt Ltd , and Tata BP Solar Pvt Ltd. in addition to CEL, BHEL, and Suryavonics) and about fifteen small units mainly engaged in BOS manufacturing and system assembly. The principal PV cell, module and systems manufacturers is CEL (see Table 3 4 3). The annual turnover of the PV industry is around Rs 50 crores.

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[26] Metkem Silicon Limited is the high technology subsidiary of the Chemplast group who are leaders in the chemical engineering industry in India Metkem silicon is one of the very few semiconductor material manufacturers in the world with the manufacturing facilities from polysilicon to silicon wafers The 35 tonne p a polysilicon manufacturing plant is located at Mettur Dam in Salem District, Tamil Nadu Metkem silicon uses an indigenous technology for the production of polysilicon that has been developed by the close interaction of the industry with the Indian Institute of Science, Bangalore The research and development activities at Metkem silicon started as early as 1976 Metkem went into commercial production in 1986

[27] This is a 100 percent export oriented unit with a licensed capacity of 3 MWp based in Hyderabad and 500 kWp capacity commissioned pilot plant for a-Si PV devices

The total installed manufacturing capacity[*] base for cells and module in India is 5.75 MWp (see Table 3.4.3) represented by two central public undertaking (CEL and BHEL), one state public unit (REIL) and four private sector units. Out of these eight units, one pilot plant (BHEL a-Si plant at Gurgaon) has not yet reached the commercialization stage, two have started shipping products recently and one is a 100% export oriented unit

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No licensing is required to start a PV industry

Table 3.4.3 Solar Photovoltaic device manufacturers in India

Name of company	**Central Public Undertaking**			**State Public Unit**	**Private Sector Units**			
	CEL	**BHEL**	**BHEL**	**REIL**	**Suryovonics**	**Tata BP Solar**	**RES**	**Udhaya**
Location	Sahibabad	Bangalore	Gurgaon	Jaipur	Hyderabad	Bangalore	Hyderabad	Coimbatore
Products	PV cells modules & systems	PV cells modules & systems	a Si modules	PV modules systems	a Si cells	PV modules & systems	PV modules & systems	PV cells/modules
Investment (Rs)	NA	NA	180 million	NA	15 million	30 million	8 million	NA
Installed capacity	1 7 MWp	25 MWp	0 5 MWp	1 0 MWp	1 MWp	0 5 Mwp	0 5 MWp	3 MWp
Capacity addition		25 MWp			2 MWp	0 5 MWp		
Production 91-92	93 MWp	23 MWp	Nil	2 MWp	----> 52 MWp ----- >			
Technology	Monocrystalline/ polycrystalline	Monocrystalline	Amorphous	Monocrystalline	Amorphous	Monocrystalline	Crystalline	Monocrystalline
Production status	In production since 1983	In production since 1984	Pilot plant under trial production	Production modules and systems since 1986 with CEL cells	Commenced production in small quantity	Supplying PV systems with BHEL cells	Supplying PV systems with BHEL cells	Production since 1989
Collaborators	In house R&D	In house R&D	Glass Tech Solar Inc USA	CEL	Energy conversion devices USA	BP Solar UK		In house
Turnover 91 92 (Rs crores)	32 5	9	Nil	7		2		
Foreign equity	NA	NA	NA	NA	80%	40%	NA	NA
Marketing channel	Direct	Direct		Direct		Dealers		Direct
Additional information		Concentration on systems Rail ways, communication	Equity with MoNES	Small systems	100% export unit	Street lighting concentration in Andamans	Equity with APEDC	

Of the seven cell and modules manufacturers, BHEL, Tata BP and Suryavonics have announced their respective future expansion plans. CEL had announced the government approval for increasing its installed production capacity to 5 MW p.a but is unlikely to exercise the option considering that the currently available installed capacity in CEL is not being fully utilized. BHEL has recently planned to double its production capacity from 0.25 MWp to 0.5 MWp p.a.. REIL is planning to set up a 1 MWp p.a cell line facility to achieve a better capacity utilization of its module line as the long-term supply of CEL cells is not guaranteed. Suryavonics, with 3 MWp licensed capacity, has only installed 1 MWp till now A further addition of 2 MWp has already been initiated. Similarly, Tata BP Solar's installed capacities of 0.5 MWp p.a is currently being upgraded to 1 MWp See Table 3.4.3 for details.

Storage battery manufacturers

There are four major private sector lead-acid storage battery manufacturers offering PV batteries in India: Chloride India Limited in Calcutta, AMOCO Batteries Limited in Bangalore, Standard Batteries Limited in Madras and UB-MEC Batteries in Bangalore. In addition, there are many small manufacturers offering similar storage batteries to the photovoltaic industry. These manufacturers normally offer off-the-shelf lead-acid storage batteries for the photovoltaic industry. Recently, Chloride has came out with a low-maintenance tubular plate lead-acid battery for photovoltaic application. This battery was originally developed for Railway and telecommunication applications. However, this has found favour with the photovoltaic industry. Remaining three and Crompton-Greaves have also come out with similar battery In addition, Tata BP Solar uses indigenously developed PV battery for its in-house designed systems Amar Raja Batteries Private Limited in Triputi in technical collaboration with GNB Industrial Battery Co., U.S.A. and Plumac Power Systems Private Limited, Hyderabad, have introduced sealed maintenance free absorbed-electrolyte lead-acid storage battery meant for PV systems among several other application All these available PV batteries come in ranges of 2 V, 6 V and 12 V with varying Ah capacity. M/s. SAB NIFE A.D., Sweden, world leaders in Nickel-cadmium batteries in a joint venture organization in Hyderabad offer NIFE-SUNICA range for PV batteries. SAB NIFE Power Systems Limited also offers a range of electronic products suitable for PV applications

Balance of System (BOS) and system manufacturers

In the BOS and integrated systems, a number of small and medium scale private sector firms have stepped in Mostly, these companies have been manufacturing electronic and electrical sub-system components and total PV systems with modules procured from one of the six module manufacturers. Ritika Systems Private Limited, a Delhi based unit having an annual turnover of Rs 2.5 crores is the largest system supplier other than the module manufacturers themselves. The unit has sold upto 20,000 PV systems so far. A few notable ones are Indfoss Industries Limited in Delhi, Solar Power Equipment in Madras, Geetanjali Electronics in Calcutta and Amar Enterprise in Bulandshahar, U P..

Constraints of the PV programme in India

Contrary to the common belief, PV systems not only require daily maintenance by a trained caretaker, but they also need regular monthly checks by a team of highly trained technicians Creation of a post-installation infrastructure often gets neglected in most installations in the country, resulting in poor field performance of the PV system as a whole. which is not due to the failure of PV device, but due to sub-standard system components and poor system design. An important factor for successful PV technology utilization in India is the reliability and credibility in the performance of existing commissioned PV systems. The acceptability and hence the future of similar or new products is largely dependent on these factors as most of the systems are supplied to users who substitute it for conventional grid electricity User awareness and participation, and the creation of appropriate service infrastructures, are two important aspects which should be developed effectively

The reliability of PV rural applications has been generally poor. Early street light installations faced numerous problems due to component failures, vandalism and poor consumer acceptance. For example, a 1990 survey in Uttar Pradesh, Maharashtra, Madhya Pradesh, Orissa, and West Bengal by the Administrative Staff College of street lights installed in five states showed that of the 4,651 systems installed, 37% had failed due to technical problems and 10% due to theft or vandalism. In Andhra Pradesh, their survey of 586 PV street lights noted that only 14 were working The same survey observed that only 3 of 20 PV pumps were operating The principal reasons for the poor reliability and performance were.

☐ Lack of involvement of the beneficiaries in decisions relating to the installation of PV and its use.
☐ Non-availability of spares.
☐ Inadequate information on systems to update design parameters.
☐ Lack of comprehensive training on system maintenance.
☐ Insufficient staff to monitor the performance.
☐ Low awareness levels about the PV systems.

The poor field performance of the PV system is not due to the failure of PV device, but often due to sub-standard system components and poor system design An important factor for successful PV technology utilization in India is the reliability and credibility in the performance of existing commissioned PV systems The acceptability and hence the future of similar or new products is largely dependent on these factors User awareness and participation, and the creation of appropriate service infrastructures are among the two important initiatives for developing a effective commercialized PV programme not requiring any Government support.

3.5 Solar thermal technologies[29]

Solar thermal energy utilization, by definition, implies the conversion of solar radiation into thermal energy, or heat. Typically, a fluid such as water is heated to elevated temperatures during day time in a solar collector, and the collected energy is either stored for later use or utilized concurrently Any system collecting solar energy would entail energy losses, and for a solar thermal energy system the losses are basically heat losses. If the geometrical area of collection is same as the area of losses, one is dealing with what is known as the flat plate collector technology or a variation of it such as solar ponds. If the geometrical area of collection is larger than the area of heat losses, one is dealing essentially with concentrating collectors.[30] Solar thermal systems have also been classified on the basis of the temperature of utilization as low (<100°C), medium (100-400°C) and high (>400°C) temperature applications.

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[29] This section is based on largely on the work of V V N Kishore

From an end-use point of view, areas of solar thermal energy utilization are traditionally classified as. solar water heating, solar cooking, solar air heating (drying), solar cooling, solar passive architecture, solar ponds, desalination, solar (thermal) water pumping, and solar (thermal) power generation. Installation of some of the solar thermal devices are presented in Table 3.5.1.

Table 3.5.1.

Installation of solar thermal systems in India as on 1.1.92	Numbers	Collector area m^2
Solar cookers	201300	50325
Domestic water heating systems	7400	18956
Industrial water heating systems	4300	161944
Air heaters/ crop dryers	52	
Timber kilns	50	
Solar stills	9100	
Solar thermal power generation units	2	(70 kW capacity)
Solar greenhouses	10	
Solarised huts	200	

The past three decades of solar (thermal) energy research worldwide witnessed the emergence of a variety of solar energy systems in which

☐ the entire system has been developed, from concept to field testing, (such as the central receiver system),

☐ the system had become feasible because of advancement in some other field (such as the development of a low temperature organic rankine engine by Ormet Systems leading to solar pond power plants) and

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[30] Depending on the nature of tracking and degree of concentration, one can further subdivide the collectors into categories such as mirror boosters, compound parabolic collectors, line focussing parabolic trough collectors and point focussing parabolic dish collectors Special types of collectors such as evacuated tubular collectors (ETCs) also exist

☐ most of the parts of system are available readily and had been put together in an ingenious way (such as the Luz system).

In the context of commercialization of the technologies, it is most appropriate to consider 'total systems' satisfying a particular end use and then examine factors such as economic viability, reliability, life etc which ultimately define the nature of R&D problems to be tackled In the following sections, a few end uses are considered separately

Solar water heating

Use of simple, low temperature collectors for providing hot water is the oldest and most widely accepted application of solar energy Judging from the number of publications, solar water heating is also perhaps the most widely researched topic. However, most of the publications in this area are soft-ware oriented, such as analysis of radiation data, modelling, long term performance predictions etc. This is because the flat plate collector technology is more or less standardized, and the use of solar systems for water/ space heating had not been unattractive from the economics point of view in the western, cold climates. Understandably, the emphasis is on domestic systems with electrical back-up, controls etc This is not to say that innovation had taken a back seat. Some of the recently developed devices such as the 'copper cricket' and boiling-condensing collector systems are examples of entrepreneur-driven inventions.

In the Indian context, solar IPH (industrial process heat) applications dominated the scene, owing perhaps to the attractive incentives like subsidy, tax benefits and low-interest loans from IREDA, in addition to the low tariff of electricity in the domestic sector. Thus, while the installed collector area was about 162,000 m^2 for industrial solar water heating systems at the beginning of 1992, the corresponding figure for domestic systems was only about 19,000 m^2 (DNES 1992) The estimated market size is 10-20 million m^2 in the industrial sector and about 1-2 million m^2 in the domestic sector In spite of such large physical potential, the solar hot water business is not exactly booming. In fact, several earlier stalwarts like Jyoti, HBB (currently ABB), and Best & Crompton have terminated manufacture of solar water heating systems The economics of the systems are perhaps responsible The net present value of benefits, in rupees, per m^2 of solar collector area for various users is shown as a function of fuel escalation rate and life in Table 3.5.2. The calculation of NPV does not take subsidy and other benefits into account, and uses the market rate for fuels (more details are available in Kishore 1991). It is obvious from Table 3.5.2 that at the present initial costs, the solar water heating system is not capable of standing on its own in the market, except when it is saving electricity round the year

Table 3.5.2. Net present value of benefits per m^2 of solar collector area for various users. (in Rupees)

e,%	Coal		Oil		Electricity	
	n=15	n=30	n=15	n=30	n=15	n=30
0	-4224	-4080	-2403	-1922	+2343	+3705
1	-4151	-3963	-2212	-1616	+2844	+4504
2	-4078	-3825	-2019	-1252	+3348	+5457
3	-3995	-3676	-1801	-859	+3917	+6495
4	-3913	-3495	-1586	-383	+4481	+7729
5	-3818	-3299	-1336	+132	+5137	+9076

Solar cooking

Nearly 40% of the entire energy consumption in India is for cooking In view of factors such as deforestation, foreign exchange crunch for import of hydrocarbons and the large potential market, cooking with solar energy will always be an attractive option. As in the last section, we shall first make an economic appraisal of the solar cooking option before examining other constraints

A levelized annual cost (LAC) approach was used in an earlier study (Kishore 1988) to calculate the cost of useful thermal energy produced by any cooking device. The results of the study show that cooking with solar energy is cheaper than cooking with electricity, but is costlier than most other available options such as LPG, kerosene, biogas, firewood etc But perhaps comparing costs in this way can be misleading because convenience, rather than cost would be the deciding factor for an essential application such as cooking. Except the solar cooker, all other devices/fuels mentioned have one thing in common - they can meet all the demands of cooking, viz, boiling, frying, baking, simmering etc. The existing box type solar cooker can only perform the boiling operation and hence is *not a complete cooking system*. It can not be used at night and during cloudy days and the cooking is slow. Solar cooker is thus a fuel-saver and an appendage to whatever cooking system one is using, though this is not a serious constraint as several cooking appliances is quite common in Indian houses The critical commercialization issue is to develop a more user friendly and convenient cooking device

The currently available box type solar cooker is too bulky to be handled easily, there is no provision to clean the space between the two windows of the double glazing, the glass wool insulation gets spoiled if the cooker is exposed to rain accidently, the quality of the utensils is poor, and the appliance comes with a fixed design, fixed cost and fixed size It is a take-it-or-leave-it appliance with no user-friendly features, and with so many other cooking appliances available off the shelf, it is not surprising that many would choose to leave it rather than take it.

Solar cooling

For most Indian locations, there would be almost a perfect match between cooling load demand and solar radiation available Thus, solar cooling can, in principle, be a very apt application for Indian conditions. CSMCRI, Bhavnagar, had put in significant efforts to develop an ammonia based absorption cooling system, and two systems, one in Gujarat, and the other in U.P., have in fact been installed on a trial basis. It appears that the systems had technical snags such as ammonia leakages etc and could not be operated on a sustainable basis. Based on items available readily in the market, a configuration consisting of a LiBr absorption cooling system, backed by an ETC field had been envisaged, and a preliminary economic analysis has been carried out (Bannerjee and Kishore 1991). The results of the analysis indicate that solar cooling is not a viable option at present, even with subsidy and other benefits. The main factor affecting the economic viability adversely is the cost of ETC panels. A hybrid system combining waste heat and ETC panels for supply of the required thermal energy, where feasible, would perhaps be more attractive R&D strategy should focus on the development of cost effective, mass producible (concentrating) high temperature collectors indigenously. This technology development efforts is likely to require time, substantial manpower and funds

Solar thermal water pumping

There had been a high level of developmental activity in solar thermal water pumps both in India and abroad from early seventies to mid eighties This period saw the emergence and closing down of many companies purporting to commercialize small (upto 2 kW) irrigation pumps using the flat plate collector technology and low temperature organic Rankine cycle engines. In India, indigenous developmental work was carried out at several labs (at some with international collaboration, the prominent being the Indo-Swiss work at CSMCRI (Bhavnagar) and at Indo-German at BHEL (Hyderabad). A reasonably high degree of success was achieved in developing prototypes and the BHEL-Dornier effort resulted in a marketable product. But there was no market for these pumps as the initial cost of the system was too high and an economic appraisal (CSIR 1983) indicated that the ratio of present worth of total costs between the solar water pump and the cheapest conventional pumpset lies between 3.0 to 6.5 for a daily overall efficiency of 0.5% achieved in the Indo-Swiss prototype (Kishore 1986). Global experience in the development of small solar water pumps till date seems to eliminate this technology as a viable alternative.

Solar drying

Solar systems for drying (or curing) of several cash-crops such as cardamom, tea and tobacco had been tried out in the past in the country. The efforts did not, however, result in demonstrable prototypes employing, for example, air heating systems, rock bed storage, etc. Preliminary estimates carried by TERI for tea drying in North-east showed that for the climatic conditions prevailing in the estates, a 100% solar system would be technically and economically non-viable Solar air heating systems for timber kilns and for drying of grapes, however, seem to have achieved a certain degree of success Also, solar pond based drying systems appear to be promising (Rao and Vaja 1991). It is quite likely that the economics are system-specific and site-specific.

R&D activity aimed at developing commercially viable packages, especially hybrid system, for drying of selected items would be worth encouraging

Solar desalination

The single stage, basin-type solar still was first developed in Australia, and still finds applications in some places. In one of the islands in the UT of Lakshadweep, a battery of solar stills is the only source of potable water The simple design allows for easy fabrication and maintenance of the system. The initial cost of the system, however, is high, and the output is low, resulting effectively in a high cost per litre of potable water A sample calculation for the system in Lakshadweep (Kishore and Sukumaran 1987) showed that the cost is about 40 p/lit., which is very high In contrast, systems operating on membrane based technologies (reverse osmosis) yield water at about 7 p/litre. The only solution for increasing the viability of a solar system is to increase the number of stages. Calculations have shown (that a solar pond based multistage flash (MSF) distillation system can yield potable water at a levelized cost of 5-7 p/lit, which is competitive with membrane based system. Most of this cost is due to the initial capital and hence the biggest advantage of such a system would be low running cost Analysis of Kishore and Sukumaran (1987) indicates that the economics of solar pond desalination system is favourable

Research efforts for development of solar pond based desalination system or any other system with favourable economics should, therefore, be supported.

Solar (thermal) power generation

Several attempts, small and big, have been made globally to develop solar thermal power generating systems. Among these four systems, viz i) solar central receiver systems, ii) solar pond power plants, iii) solar dish-stirling systems and iv) distributed linear parabolic collector system with natural gas back up (Luz system) deserves particular attention as these came closest to commercialization. This subject has been discussed in detail elsewhere (Kishore and Thukral 1987), and only the results that none of the direct solar systems is economically viable at present, but a few points regarding the Luz system are worth noting

The Luz system is essentially a hybrid system, and it has been estimated that if it could be operated in a 100% solar mode, the cost of electricity would be about 3.5 Rs/kWh (Kishore and Thukral 1987). With the ingenious concept of utilizing natural gas for superheating the steam, the Luz system could become commercially viable in California, albeit with advantages of the tax credits etc. available in that state The company has is reportedly bankrupt and there are no commercially viable solar thermal power plants at present.

Valuable lessons, however, have been learnt. It is becoming apparent that the future of solar power plants lies in developing viable concentrating systems. It is also apparent that hybrid systems have a better chance of survival than 100% solar systems. But, with the failure of mega efforts like central receiver systems, Luz etc., it would take an enormous degree of conviction and environmental concern on the part of any government, including Indian, to embark upon similar programmes, considering especially the technological sophistication and the magnitude of funds involved

3.6 Biogas technology[31]

Biogas is a unique technology that provides both fuel and manure (without biogas plants only either of these is possible), makes optimal use of local resources such as cowdung and other organic-wastes, helps to develop indigenous growth using local skills and technologies, provides relief from drudgery, and leads to environmental improvement.

The National Project on Biogas Development (NPBD), launched in late 1981, is the largest (in terms of funding) renewable energy programme in India[32] and in the last decade over 1.4 million household sized plants have been installed. About 750,000 plants are targeted for the Eighth Plan period.

The NPBD is implemented as a multi-model, multi-agency programme with the hope that biogas plants suited to local conditions would be installed and would attract active participation of NGOs (non-governmental organizations). Lead Banks in each district co-ordinate the loan sanctioning activity with other banks and institutions.

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[31] This section is largely based the work of Venkata Ramana P

[32] The NPBD, till 1992, has consistently accounted for over half of the central allocation for the renewable sector In the Eighth Plan, however, the central allocation of Rs 320 crores is under 40% of the allocation for the renewable sector

Initially MoNES approved the floating dome model of KVIC and Janata model of PRAD for implementation by the NPBD Subsequently four other models were included in the programme -- 'Deenbandhu', ferro-cement model, 'Pragati' and 'Ganesh'. MoNES further devised a detailed subsidy pattern based on the physical and economic disparities existing in different parts of the country.

Although biogas has been a success in several states, its presence is merely a token in the North-east and Himalayan region. Difficult terrain and high transportation costs coupled with lack of trained manpower have rendered the dissemination of biogas in the remote and hilly regions difficult.

To evaluate the performance of the NPBD, the MoNES commissioned private consultants to conduct two surveys in 1985/86 and 1987/88 respectively. The first survey covered 10883 plants across 12 states while the latter covered 19842 plants in 23 states. Together the sample represented 4.18% of the total plants set up till 1986/87. The evaluation reported an overall success rate of 87.9% and 84.3% in 1985/86 and 1987-88, respectively. A few evaluation studies carried out later, independent of MoNES at micro level also indicated that the NPBD may not have been an unqualified success. Studies showed Wardha district, Maharashtra, with a 48% functioning rate Udaipur, Rajasthan 40%; and, Marathwada of Maharashtra region a meagre 4% Another survey of the biogas plants set up by KVIC revealed that over 30% of these were defunct. The CAG (Comptroller and Auditor General) Report of 1984-85 said that the success rate was not 85% as claimed but only 58%.[33]

Thus, the overall picture comes out to be a mixed one as far as the performance of the biogas plants is concerned. Moreover, no information is available on whether all the functioning plants are producing gas to their designed capacity. Also, there is no firm evidence that all the slurry produced is being utilized as fertilizer. Therefore, the claim of annual savings worth Rs 350 crores does not seem to be realistic. Nevertheless, even at a

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[33] More disturbing was the CAG observation that several malpractices found in the implementation of NPBD such as misreporting of achievements, financial irregularities, and shortcomings in user selection, design selection and training courses which led to the failure of a large number of plants

58 per cent functioning rate, the savings could be considerable

The reasons for plants becoming dysfunctional can be broadly divided into two categories - structural (construction-related problems) and operational. Nearly two-thirds of the dysfunction al plants surveyed in 1985-86 (by MoNES-commissioned studies) suffered from operational problems with structural defects ac counting for the remainder; the ratio for the same was 75:25 in 1987-88.

The popularity of the Janata and Deenbandhu (after 1986) models under the NPBD was marred by structural problems that caused maximum failure in Janata plants - as high as, 50% in many a state The masonry dome of the Janata model requires good engineering skills to build, and a defective plant could crack easily because of gas leakages On the other hand, the major problem with KVIC is the corrosion of the metal dome that leads to leakages and it needs repainting once a year However, KVIC plants were also reported to have suffered structural failures such as sinking of foundation and collapse of the central wall in the digester For instance, 77% of the dysfunctional plants in Karnataka and 62% in Maharashtra failed owing to these structural problems.

On the operational side, the main stumbling block is the dung required for initial charging At least 30 quintals of dung is needed for charging a 2 m^3 plant which poor households are unlikely to generate, or can afford to buy it. In Marathwada 95% of the non-commissioned plants could not be operated owing to non-availability of dung

Underfeeding of dung and water is another major problem resulting in inadequate gas production that has led to user dissatisfaction Normally the assumptions about dung yield, collection rates and gas production rates from dung tended to be on the higher side due to which bigger sized plants were constructed For instance, KVIC put 2-3 heads of cattle as the minimum needed to set up a 2 m^3 plant whereas other estimates recommended 4-5 heads. But, lack of user education is also responsible for underfeeding or mixing the dung and water in wrong proportions.

Insufficient water supply is a serious problem for biogas plants. It is estimated that 55 litres of water is the daily requirement of a 2 m^3 biogas plant. Consequently where water shortages occur, the time likely to be saved in fuel collection by using gas is offset by fetching water, if at all available. One-third of the commissioned plants in Marathwada suffered from water shortages while CAG reported that thousands of plants constructed in Rajasthan remained uncommissioned for more than a year because of drought conditions.

The problems usually encountered during operation have been choking of the pipelines by water accumulation, and scum formation in the digester, clogging the inlet and outlet. Lack of proper guidance and service by the implementing agencies has largely contributed to these Twenty per cent of the plants surveyed in Maharashtra and 25% in Karnataka continued to suffer for want of service.

Besides the above problems a major difficulty faced is the paucity of funds, even for small repairs because of which many plants belonging to the poor had to be abandoned More than half the defective plants in Karnataka and Maharashtra could not be repaired owing to financial limitations of the owners. A majority of the non-functioning plants in Gujarat belonged to the weaker sections of the population. Halfway through the project, MoNES became aware of the need for institutional finance, and in 1984/85 launched a rectification programme, under which Rs 500 to Rs 1000 was sanctioned per plant for repairs. More than 30,000 plants were reported to have been revived under this scheme till 1987.

Impact of NPBD

Since its initiation almost a decade ago NPBD has made tremendous progress in disseminating biogas technology on an extensive scale Apart from being an efficient fuel for cooking, biogas has found other uses such as lighting.

Despite the existence of 1.4 million (upto 1990/91) plants biogas cannot be said to have made any impact on the total rural energy scenario because only about 1% of the total households benefits from biogas One serious limitation has been the near-total dependence on cattle dung as the feedstock which allows only a fraction of the households, who possess the requisite number of cattle and are usually well-to-do, to install such plants This indicates a need to find and promote alternative feedstocks but research efforts have been unsuccessful in developing a plant that uses other feed stocks such as agricultural wastes at the field level

Nevertheless, biogas plants in operation have certainly benefitted the individual families by replacing the traditional fuels to a large extent Sharp decrease in the use of kerosene, wood and dung-cakes was observed in Karnataka, Maharashtra, Himachal Pradesh, etc. Moreover, the housewives were happy with the smokelessness, time saving and fuel saving through biogas use.

Studies indicated that the majority of the plants were owned by the rich, educated sections of population which otherwise could afford other expensive fuels. For instance, only 2 to 5% of the biogas plant owners in Karnataka and Maharashtra, 10% in Marathwada and 20% in Gujarat belonged to scheduled caste and scheduled tribe communities. In Madhya Pradesh, none of the 775 plants surveyed belonged to a family from these categories. In fact, another study in Madhya Pradesh showed that most plant owners were affluent professionals such as doctors and lawyers. Limited access to cattle, water, land, and, more importantly, cash, has become a natural constraint for the poor.

Community biogas plants

In order to make biogas accessible to poorer sections of the population, which do not possess sufficient number of cattle, CBPs (community biogas plants) were recommended. Under the scheme dung is supplied to the plant by those who own cattle (at a cost) and the gas is sold to those who cannot provide the input. In this context, CBPs were considered socially more appropriate. Moreover, CBPs were envisaged as potential nuclei for development of decentralized energy systems to catalyse rural development programmes. These would help to transform village life by providing not only efficient cooking fuel, but also electricity for lighting, cottage industries, irrigation and drinking water supply, and sanitary toilets and fertilizer for improved agriculture.

With such objectives in mind, the Rural Electrification Corporation established the first CBP in the country at Kodumunja village in Andhra Pradesh in 1977. CBPs received a thrust when MoNES launched, along with its NPBD, an All India Coordinated Project for demonstration-cum-experimental community/institutional biogas plants. Initially, MoNES offered 100% subsidy for CBPs and 75% for IBPs (institutional biogas plant) (those set up by institutions such as dairies and, hospitals, but revised the rates to 90% ad 70% respectively by the end of 1986. Further, MoNES would bear the maintenance costs of the plant for 6-12 months before handing it over to the village panchayat or the co-operative.

At the end of 1989-90, 504 biogas systems were set up at a cost of nearly Rs 20 crores, of which 254 were CBPs, 243 IBPs and 7 NBPs (Night-soil Biogas Plants) and this had gone up to about 700 at the beginning of 1992. However, more than 90% of these systems were concentrated in just 8 states, with Punjab and Maharashtra having over 125 plants each.

Though the project made good progress numerically, there is very little information available on the performance of the CBPs Whatever that was available, was mainly on the CBPs installed under DST project, which were studied by Indian Institution of Management, Ahmedabad and National Council for Applied Economic Research, New Delhi, commissioned to study the socio-economic and administrative aspects of the community plants over a period of three years, and on the CBPs installed prior to that. The evaluation of 34 selected CBPs, does not present a very encouraging picture. Of this total, 3 were never commissioned and 11 became defunct after working for periods varying from 3 months to 3 years Among the 20 plants reported functioning, just two were operating at full capacity while 10 plants were working at less than half the capacity, and 13 of the plants were running at monetary losses ranging from Rs 100 to Rs 2200 per month.

Based on the analyses presented in the studies, the reasons for variations in performance of CBPs are as follows.

1 absence of community participation owing to factionalism or lack of interest on the part of the managing agency (panchayat, co-operative society, etc.),
2 improper planning in terms of dung estimation, site selection, gas distribution, etc.,
3 inadequate maintenance resulting in irregular dung collection, underfeeding, slow slurry disposal, etc., and
4 inability of the poor to pay even the monthly charges of Rs 30 to Rs 50

Among these, lack of community participation emerges as the basic constraint for community plants. In Indian villages, it is generally the affluent which controls resources required for biogas production, including dung, and it is not easy to acquire such inputs for CBPs, especially when the gas is to be sup plied to the poor. Thus, most of the dysfunctional plants owed their failure to this reason. In majority of the commissioned plants, the dung supply was irregular and gradually declined, decreasing the gas supply which in turn reduced the gas connections To compensate for the short supply households kept larger amounts of dung for cakes, decreasing dung supply which further reduced the gas. Caught in this vicious circle, many CBPs came to a halt finally. Even the planners overestimated the quantity of dung available, which led to higher capacities of plants and more gas connections but less gas.

However, as the experience of successful CBPs like Kheri Bhai Ki in Punjab, and Methan and Motipura in Gujarat illustrates, there are two conditions necessary for a smooth functioning of CBPs:

1 the village should have a cohesive population with some uniformity in lifestyle and affluence, and
2 the village must have a strong and enlightened leader ship to motivate and unite the people.

It is difficult to envisage in how many villages in India such conditions exist but as of now, performance of CBPs remains an open issue.

3.7 Improved cookstoves[34]

Two types of cookstoves are normally used in Indian kitchens, namely the fixed model and the portable model The fixed model made of mud[35] and is usually constructed in the kitchen by the owners themselves The portable model is made of sheet metal and is usually manufactured by village artisans and blacksmiths.

Improved designs of the fixed model incorporate modified flue gas passages and additional features (baffle, swirl chamber, etc) to increase useful heat transfer to the cooking vessel They also feature a chimney which provides a safe outlet for escaping flue gases thus shielding the cook from any harmful consequences of exposure to smoke. Portable models consist of modified and slightly more complicated designs for the combustion chamber, grate, etc. which help in enhancing useful heat transfer capability of the device. While improved versions of the fixed model have been found to have an efficiency in excess of 20%, the portable designs were found to have efficiency values even of the order of 30% *in the lab.* These features and performance characteristics are highly suggestive of the fact that such improved models have the potentiality to save fuel.

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[34] This section is based largely on the work of Veena Joshi and Parimal M Sadaphal

[35] In some areas some other materials like bricks, stones or pottery may also be used to support the mud structure.

Realizing the potential benefits that could accrue as a result of large scale adoption of improved cookstoves in the country, the MoNES launched the National Programme on Improved Chulhas (NPIC). The programme aimed at optimizing the use of fuelwood, eliminating smoke from the kitchens, reducing drudgery of women, improving their health and employment generation through introduction of improved cookstoves

Over 10 million improved cookstoves have been installed since the inception of the programme in 1983. Initially fixed models made of mud or pottery and portable models were approved for installation under this programme. The installations were almost fully subsidized with the users' contribution being Rs 5/- which was paid to the person installing the cookstove. Presently, the cookstoves cost[36] about Rs 50/- to Rs. 100/- and the beneficiaries are supposed to contribute Rs 10/- By the end of the current financial year the total number of cookstoves installed is likely to exceed 12.5 million. The implementation of the programme was mostly done by government agencies themselves, however, a part of it was also done by voluntary agencies.

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[36] Portable models could cost upto Rs 165/-

Table 3.7.1. An Assessment of NPIC.

State	No of ICs Surveyed	Cookstove Use Statistics (% of ICs surveyed)			Comments
		Demolished/ Discarded	Use	Part time or mostly	Used fully
Himachal	374	53	7	40	33% mentioned Pradesh excess fuel need and none mentioned saving
Haryana	282	66	8	26	Fuel saving only for case of cookstoves during a well conducted training course
Punjab	49	22	49	29	About 30 to 50% report excess fuel use
Gujarat	180	33	-	31	36% were converted to TC None reported saving
Orissa	29	69	-	31	A more exhaustive survey indicates 30% usage

Source: Joshi et al. 1990

CHAPTER 4

Trends in energy demand

4.1 Introduction

India is dependent on fossil fuels for meeting its commercial energy requirements. It has moved from being largely a biomass based economy at the time of independence to a 60% dependence on commercial energy forms Coal and petroleum products form the main energy sources although the share of natural gas is increasing quite rapidly.

A broad sectoral analysis of energy demand reveals that the fastest growing sectors, in terms of energy consumption, are the agricultural and the residential sectors wherein consumption has grown at an annual rate of 10.5% and 9.6% respectively during the period 1972-73 to 1988-89 (Table 4.1). In terms of absolute energy consumption, the industrial sector accounts for a major part followed by the transport sector. Utilization of various energy forms for non-energy purposes (naphtha as feedstock, lubes and greases and natural gas used in industry) has also increased rapidly, at about 5.8% per annum, during the same time period.

An analysis of energy demand by fuel reveals that the share of industry in total electricity consumption has declined over the period 1980-81 to 1988-89 while that of the agricultural and residential sectors has increased quite significantly The residential electricity demands have gone up from 11% to 14% of total electricity demands. This is significant because these demands are found to coincide with the peak demand In case of the agricultural sector the increase in demand is largely due to the Government policy of rural electrification and thereby energisation of pump-sets The state electricity boards, however, adopt a number of measures to ensure that rural pump-sets do not operate during periods of system peak demand.

Table 4.1.1. Trends in availability and consumption of commercial energy 1972 73 to 1988 89

(million tonnes of oil equivalent

Year	Gross availability	Conversion losses	Net availability	Agriculture	Industry	Transport	Residential uses	Other energy uses	Non energy consumption (col4 9)
1972-73	68 483	14 396	54 087	0 78	29 717	13 579	4 533	1 542	3 936
	(100 0)	(1 4)	(54 9)	(25 1)	(8 4)	(2 9)	(7 3)		
1980-81	92 623	23 859	68 764	1 625	36 861	17 443	5 637	1 901	5 297
	(100 0)	(2 3)	(53 6)	(25 4)	(8 2)	(2 8)	(7 7)		
1982-83	109 023	28 552	80 471	1 861	44 225	18 758	6 82	2 127	6 68
	(100 0)	(2 3)	(55 0)	(23 3)	(8 5)	(2 6)	(8 3)		
1984-85	121 51	34 997	86 513	2 131	46 595	20 309	8 038	2 341	7 099
	(100 0)	(2 5)	(53 8)	(23 5)	(9 3)	(2 7)	(8 5)		
1986-87	141 187	40 927	100 26	2 807	53 423	22 789	9 532	2 677	9 032
	(100 0)	(2 8)	(53 3)	(22 7)	(9 5)	(2 7)	(9 0)		
1988-89	163 606	52 621	110 985	3 861	56 214	26 055	11 532	3 684	9 639
	(100 0)	(3 5)	(50 6)	(23 5)	(10 4)	(3 3)	(8 7)		

Source : Compiled from energy balances in TERI, 1990

Note : Figures in brackets give percentage shares

The share of the transport sector in oil consumption has been increasing due to the absence of an alternative transportation fuel both in the road sector as well as in railways. Electrification of rail routes is limited by the density of traffic required to make this an economically viable option Similarly, in the domestic sector the only commercial energy alternative to cooking fuels is petroleum based products. Both these factors have contributed to the disproportionately large demand for middle distillates (kerosene and diesel) in India.

In 1990-91, close to 61% of coal consumption was accounted for by the power sector and 35% by the industrial sector Coal consumption by railways is declining due to a conscious policy adopted by the Government of India to phase out the highly inefficient steam locomotion and replace them with diesel and electric traction

Natural gas consumption in the country is still extremely low with well over 30% of natural gas produced being flared in 1989-90 Industry accounts for close to 98% of the gas that is consumed, largely in fertilizer and petrochemicals industries (non-energy purposes) and for power generation.

4.2 Energy demand in 2010

Assumptions

Given the past growth and pattern of energy demand the present study attempts to provide snapshot pictures of future energy demands To do so, energy demands have been disaggregated regionally and projected into the future using an end-use approach. Sectoral growths are first estimated and then useful energy consumption norms applied to them. Next, these useful energy demands are distributed over alternative fuels taking into account efficiencies of utilization, availability of various fuel types and population distribution patterns. Demands scenarios assumed in this study are given below.

(a) GDP grows at an average real rate of 5% per annum.

(b) The population growth rates estimated by the Standing Committee of Experts on the Population Projections (Planning Commission), October 1988 are used with some modifications. Population grows at an annual rate of growth of 2.01% up to the year 1999- 2000 and 1.81% thereafter till 2009-10. By extrapolation of past trends the share of northern region in total population increases from 28.7% in 1991 to 30.4% in 2009-10, while those of southern and western regions decline from 23.3% and 22.2% to 21.8% and 21 7% respectively over the same time period. Shares of the eastern and north eastern regions remain unchanged.

(c) Urbanization at the national level increases from 27.5% in 1991 to 37.5% in 2009-10. This trend is estimated on the basis of projections made by the Planning Commission (GOI, October 1985).

(d) In the agriculture sector, the output grows at an annual rate of growth of 3% This is in consonance with the Planning Commission projections up to the year 2000

(e) For industry, the following growth rates have been assumed textiles: 4%, electrical machinery: 11.8%, non-electrical machinery· 12 5%, chemicals and petrochemicals. 9%, iron and steel (mini plants)· 11.79%, aluminium: 7.7%, cement: 7.3%, paper. 4% and fertilizer. 5.7%. These growth rates are obtained from the Plan document or based on the opinion of experts in these areas. The iron and steel production is projected on the basis of project-wise capacities under construction up to the year 2004-05 (Centre for Monitoring the Indian Economy, 1989) and extrapolated to the year 2009-10 at an annual rate of growth of 2.9%, the estimated average rate of growth projected for the period 1999-2000 and 2004-05.

(f) In the transport sector, the rail:road mix (in%) changes from 20 80 in 1988-89 to 13:87 in 2009-10 in case of passenger transport and from 48:52 to 35:65 over the same time frame in case of freight transport The Steering Committee on Perspective Planning for Transport Development, Planning Commission has worked out these shares for 1987-88 and projected them for the year 2000. For analytical purposes, the rail-road mix in 1989-90 and 1994-95 is worked out by linear interpolation while in 2004-05 and 2009-10 these are assumed to be at 2000 level. In general, the share of roadways increases at the expense of rail transportation.

Within railways, the share of coal engines declines exponentially and becomes negligible by the year 2004-05, while the shares of both electric and diesel traction increase at varying rates in different regions of the country based on past trends. In case of road transportation, the shares of different modes are an average of the observed shares during the period 1980-81 to 1984-85, buses account for more than 80% in total passenger transportation and trucks (both LCVs and HCVs) account for over 97% of total freight transportation

(g) In the urban residential sector, by fitting a log- normal curve, the income distribution of population changes in such a manner that there is a decrease in the percentage of population in the lowest income bracket. Large sections of population graduate into higher income brackets thus leading to about 25% of population in the highest bracket in 2009-10 as against a mere 9.5% in 1990-91

(h) The estimates of energy demand for the rural domestic sector is based on a normative thermal energy demand of 520 kcal per capita daily (and this is assumed to be constant in the period of the projection time horizon). The fuel mix used in the estimates (and the projections) are based on the state-wise estimates indicated by the domestic fuel survey of NCAER in 1979.

There is very little evidence of a correlation between energy consumption and income, even if it could be established that the benefits of economic growth percolate to rural areas. As a result of this, the volume effects (changes in the energy demand due to the expansion the economy) of the energy demand estimates and projection just include historical growth of the population Lack of information on the structural changes and the likely impacts of such changes precludes its inclusion in the demand projection for this sector.

(i) The kerosene consumption for lighting purposes is assumed to be accounting 60% of total kerosene.

Demand for different fuels

The sectoral energy demands that have been estimated in the previous sections have been aggregated and corrected for the likely consumption by commercial and other sectors to arrive at total energy demands

Electricity demand

Table 4.2.1. Demand projections for electricity (GWh)

	North	West	South	East	N East	All-India
1994-95						
Industry	21381.13	47806.74	36137.33	20975.43	1829.66	128130
Transport	1803.55	1319.87	1208.61	1336.61	409.21	6077.85
Domestic	15872.91	13848.54	11258.91	5454.38	939.98	47374.73
Agriculture	43231.00	18802.00	16400.00	13684.00	58.00	92175.00
Others	9143.00	9086.00	7223.00	4606.00	360.00	30418.00
TOTAL	91431.00	90863.00	72228.00	46056.00	3597.00	304175.00
1999-2000						
Industry	29918.30	65622.92	51302.51	26136.29	2384.95	175365.00
Transport	2107.11	1434.78	1309.77	1481.09	468.01	6800.77
Domestic	20940.62	15895.90	13954.56	6843.42	1183.80	58818.30
Agriculture	48272.00	21464.00	19143.00	16262.00	70.00	105211.00
Others	11249.00	11602.00	9523.00	5636.00	456.00	38466.00
TOTAL	112487.00	116019.00	95233.00	56358.00	4563.00	384661.00
2004-05						
Industry	43632.12	93370.25	72712.30	34810.50	3222.73	247748.00
Transport	2973.33	1998.37	1752.36	2023.99	673.25	9421.29
Domestic	28003.85	18105.75	17286.94	8490.07	1558.53	73445.14
Agriculture	54139.00	24540.00	22365.00	19259.00	83.00	120387.00
Others	14305.00	15335.00	12680.00	7176.00	615.00	50111.00
TOTAL	143054.00	153349.00	126796.00	71760.00	6153.00	501113.00
2009-10						
Industry	64885.22	134712	106791	48545.36	4435.42	359369.00
Transport	4175.46	2772.06	2337.71	2750.72	962.10	12998.05
Domestic	37503.36	22742.50	21656.57	10920.77	2122.83	94946.03
Agriculture	60926.00	28095.00	26157.00	22744.00	99.00	138021.00
Others	18610.00	20925.00	17438.00	9440.00	847.00	67259.00
TOTAL	186100.00	209247.00	174379.00	94401.00	8466.00	672593.00

In terms of percentage shares, it is seen that the industrial sector's consumption of electricity has increased from the present level of approximately 47% to over 53% in 2009-10. Shares of the domestic and agricultural sectors have declined to 14% and 21% from 17.5% and 23% respectively. The All-India peak demand is seen to increase from a level of 42,000 MW in 1989-90 to 115,000 MW in 2009-10. The growth in peak demand is lower than that of electricity due to the increasing share of the industrial sector which has a much smoother load profile vis-a-vis the domestic sector.

Coal demand

Table 4.2.2. Demand projections for coal (million tonnes)

	North	West	South	East	N East	All-India
1994-95						
Industry	10.39	32.75	27.49	37.38	0.90	108.91
Power	41.18	58.97	29.12	38.02	1.31	168.61
Transport	1.83	0.62	0.50	1.17	0.39	4.51
Domestic	0.69	0.84	0.04	0.35	0.05	1.98
Others	6.01	10.35	6.35	8.55	0.30	31.56
TOTAL	60.09	103.53	63.50	85.47	2.95	315.56
1999-2000						
Industry	12.19	37.02	34.99	38.11	0.86	123.18
Power	55.58	74.10	40.33	50.83	1.31	222.15
Transport	1.69	0.40	0.31	0.88	0.33	3.60
Domestic	0.86	1.01	0.05	0.44	0.07	2.43
Others	7.81	12.50	8.41	10.03	0.29	39.04
TOTAL	78.14	125.03	84.09	100.29	2.85	390.41
2004-05						
Industry	16.21	47.15	41.50	42.31	0.95	148.11
Power	74.50	89.89	55.68	65.31	1.31	286.70
Transport	1.90	0.34	0.24	0.82	0.36	3.67
Domestic	0.98	1.23	0.07	0.51	0.08	2.87
Others	10.40	15.40	10.83	12.11	0.30	49.04
TOTAL	104.00	154.00	108.31	121.05	3.01	490.39
2009-10						
Industry	21.68	59.35	53.35	49.40	1.09	184.87
Power	104.56	115.00	80.08	88.33	1.31	389.29
Transport	2.15	0.29	0.18	0.78	0.41	3.81
Domestic	1.11	1.47	0.08	0.57	0.10	3.33
Others	14.39	19.57	14.85	15.45	0.32	64.59
TOTAL	143.89	195.68	148.55	154.53	3.23	645.89

No major changes are seen in the case of coal consumption, with industry and power continuing to account for close to 90% of total coal consumption. However, the share of the power sector has increased from about 57% to 60% at the cost of industrial coal consumption While the transport sector still consumes nearly 4 million tonnes of coal, in percentage terms its share is almost negligible at 0.5%. An interesting thing to note is that the share of Western region in total coal consumption has declined while that of the Northern and Southern regions has increased The share of the Eastern region wherein most of the coal is found is also seen to be declining probably due to relatively lower level of developments as compared to the other regions.

Oil demand

Table 4.2.3. Demand projections for oil ('000 tonnes)

	North	South	West	East	N East	All-India
1994-95						
Industry	2985 00	3185 00	7203 00	1884 00	264 00	15522 00
Power	926 60	655 17	1326 76	855 56	29 57	3793 66
Transport	11095 29	7920 76	8434 75	6709 44	1074 57	37444 81
Domestic	2777 41	3534 64	4116 75	1984 85	532 68	12943 84
Agriculture	3075 69	875 37	1117 67	680 77	21 18	5770 67
Others	1211 26	1020 97	1634 11	703.03	91 51	4660 88
Total	22071 42	17192 08	23833.20	12818 08	2013 41	80135 69
1999-00						
Industry	3602 00	4081 00	8936 00	2398 00	309 00	19326 00
Power	1250 51	907 43	1667 16	1143 64	29 57	4998 30
Transport	16215.36	10833 35	11609 06	9352 01	1516 88	52246 66
Domestic	3414 32	4066 92	4701 87	2370 00	613 01	15163 61
Agriculture	3605 58	1056 29	1330 48	824 32	27 95	6844 62
Others	1640 16	1367 12	2168 06	945 61	124 26	6245 20
Total	29727 50	22311 74	30412 96	17033 39	2621 00	104824 1
2004-05						
Industry	4535 00	5342 00	11534.00	3238 00	377 00	25026 00
Power	1676 19	1252 84	2022 60	1469 53	29 57	6450 72
Transport	21839 53	13858 29	15018 02	12185 21	2011 96	68273 01
Domestic	4209 58	4755 69	5552 23	2898 45	729 77	18145 72
Agriculture	4219 69	1275 18	1579 58	992 07	36 15	8102 67
Others	2175 88	1807 95	2910 76	1272 14	165 56	8332 27
Total	38655 54	28291 90	38617 42	22055 85	3349 75	134330
2009-10						
Industry	6029 00	7344 00	15408 00	4525 00	479 00	33785 00
Power	2352 69	1801 79	2587 49	1987 44	29 57	8758 98
Transport	29415 93	17778 18	19467 57	15931 55	2678 29	89381 52
Domestic	5196 22	5580 09	6528 85	3499 72	867 88	21675 25
Agriculture	4932 45	1540 93	1871 96	1187 98	46 07	9579 40
Others	2924 61	2436 34	3959 10	1734 17	222 24	11276 46
Total	50851.26	36481 06	49823.00	28865 72	4323 19	174456 7

The transport sector continues to account for a large part of total oil demand (51%) up to the year 2009-10. The other major consumer is the industrial sector whose share has decreased to about 19% of total oil consumption (24% including power). The share of the domestic sector (12.42%) in this scenario is seen to be declining largely due to the assumption that the per capita kerosene consumption in rural areas would remain at present levels. Thus, kerosene consumption in rural areas is increasing only at the rate of growth of the population. The share of agriculture in oil consumption works out to about 5.5%.

Demand for natural gas

Table 4.2.4. Demand projections for natural gas

	North	South	West	East	N East	All-India
1994-95						
Industry	1708.08	1036.50	3237.33	333.50	143.04	6458.45
Power	6400.58	1759.66	6138.11	374.40	2196.12	16868.86
Total	8108.66	2796.16	9375.44	707.90	2339.16	23327.31
1999-00						
Industry	2685.02	2002.64	5308.95	531.70	250.97	10779.29
Power	8830.20	2701.56	9773.68	374.40	4288.79	25968.63
Total	11515.22	4704.20	15082.63	906.10	4539.76	36747.92
2004-05						
Industry	3917.32	2995.68	7873.59	764.99	377.22	15928.80
Power	9421.35	3273.00	11547.13	374.40	6259.29	30875.17
Total	13338.67	6268.68	19420.72	1139.39	6636.51	46803.97
2009-10						
Industry	5691.51	4624.02	11959.38	1070.57	578.21	23923.70
Power	10360.84	4181.17	14365.58	374.40	9390.90	38672.88
Total	16052.35	8805.19	26324.96	1444.97	9969.11	62596.58

Natural gas consumption would increase at a rate of 9% per annum over the period 1989-90 to 2009-10. The power sector would account for close to 62% of this demand, the balance being made up by industry. Significantly, the share of the North-Eastern sector in natural gas consumption has increased to about 16% from a level of well below 10% today. The share of the Western and the Southern regions has increased while that of the North has declined.

The above analysis shows the changing mix of energy sources with the South increasing its share of both coal and gas consumption and thereby electricity consumption as well and the West reducing its dependence on coal while making increasing use of gas. The Eastern region exhibits declining shares in the consumption of almost all energy sources

Demand for biomass fuels

Table 4.2.5. Projection of regional consumption of fuels in domestic sector of rural areas

	1990-1991	1994-1995	1999-2000	2004-2005	2009-2010
Firewood (mt/y)	118 30	126 45	135 01	143 97	153 31
Agricultural waste (Air dry) (mt/y)					
North	13 69	14 79	15 95	17 20	18 51
West	5 82	6 26	6 72	7 20	7 69
South	11 88	12 41	12 94	13 48	14 01
East	20 74	22 65	24 73	26 99	29 45
North-east	3 19	3 48	3 79	4 13	4 49
TOTAL	55 33	59 59	64 14	68 99	74 16
Animal waste (Air dry) (mt/y)	78 67	84 86	91 45	98 44	105 85
Kerosene (mt/y)	3 09	3 31	3 55	3 80	4 06

CHAPTER 5
Review of energy policies

In this chapter the growth of energy sector is briefly described and reviewed. The recommendations made by the specific committees set up by the Government to review energy policy from time to time are summarized. The issues involved in energy conservation, energy pricing policies and the renewable energy development programmes are discussed separately due to their critical importance at this juncture in the country's development.

5.1 Growth of energy sector

In the First Five Year Plan the Electricity Supply Act was promulgated which stipulated that power generation should be carefully regulated and sold at economic rates. The rapid increase in hydro capacity was primarily to feed infrastructure industries and to meet urban demand During this period it was realized that entrusting the State Governments with power sector developments was insufficient and Central Government involvement would be a pre-requisite to successful programme formulation and implementation. The result of these activities was that the growth of the energy sector outstripped overall economic growth.

Prior to independence the oil sector was dominated by Burmah-Shell, Standard Vacuum Oil Company and Caltex. In the 1950s the Government persuaded the oil companies to import crude rather than petroleum products, which led to a reduction in the total import bill. Domestic product prices, however, did not reflect any change as the multinationals set prices equal to product prices in the Middle East, plus freight and handling charges, etc In order to break this, the Government set up three refineries - two in the Eastern region and one in the Western region - to make use of indigenously produced oil in the region This led to the establishment of the ONGC in 1956. In 1958, a major event for national control of oil exploration occurred with the discovery of the

Cambay gas field. Other discoveries followed in the next 3-4 years. The oil available indigenously was beneficial for Indian consumption in economic terms and this is borne out by the fact that the price of oil supplied by the ONGC to Indian refineries has been consistently lower than the price of imported oil obtained by the multinationals.

The Second Five Year Plan emphasized the development of the capital goods sector and infrastructural industries through direct government investments. This led to the growth and expansion of capacity and production in the capital goods sector, an energy intensive sector. This in turn implied that demand for power increased to outstrip supply and marked the beginnings of our current power problems. During the Third Five Year Plan the primary emphasis was on power generation. During this plan, ONGC's exploration activities gained momentum.

The Fourth Five Year Plan emphasized the indigenization of equipment for thermal power plants. Primary emphasis was laid on the transmission and distribution of power. Regional Electricity Boards were set up in the country to try and achieve the goal of integrated power development and regional sharing of power for optimal use.

The Fifth Five Year Plan emphasized on building up self reliance in food and energy. The apex bodies for coordinating activities of thermal and hydro power development were constituted i.e , the National Thermal Power Corporation and the National Hydro Power Corporation. Rural electrification was accorded priority and subsidies were granted for supplying power to rural areas In addition, the tariff structures for the State Electricity Boards were also finalized.

The Fuel Policy Committee of 1974 felt that inter-fuel substitution was required in all sectors of the economy. The transport sector however, was to be exempt from this substitution However, for an integrated energy sector to emerge, detailed information on the nature of energy source deposits and improvements in the transport facilities were a pre-requisite, for which investments were required. The Committee suggested the establishment of regional grids and location of thermal power plants near pitheads to reduce the coal transport requirements. It also stressed popularizing the use of gobar gas as an attempt to reduce the environmental impacts of conventional energy use. Coal beneficiation was suggested as a method of mitigating the environmental impacts.

In 1979, another Committee - the Working Group on Energy Policy was constituted. The main recommendations of the Committee were that the rate of growth of energy should be curtailed and fuel utilization patterns optimized. The need for sustained and comprehensive central directives in evolving policy options on a continuous basis was highlighted. In addition, suitable policies for non-commercial energy sources and alternate energy sources were explored Better management and marketing was required for commercialization of renewable sources of energy. In order to achieve these various goals, an increase in the R&D expenditure in the energy sector was required. The basic thrust areas of this R&D expenditure would be in improvements and adaptation of existing technologies, with special emphasis on conservation, the development of more efficient technologies for utilizing indigenously available conventional sources of energy and for development of renewables in energy production.

In the Sixth Five Year Plan the main elements of the strategy were the accelerated exploitation of domestic conventional energy resources, effective management of oil demand, energy conservation, exploitation of renewable sources of energy e.g forestry and biogas and increasing investment outlays for R&D in emerging energy technologies

In 1983 the Inter-Ministerial Working Group (IMWG) made specific suggestions with regard to energy conservation The IMWG felt that the absence of coordination in the implementation of energy conservation programmes in the country as well as a lack of shouldering of responsibility for the implementation of the programme could be rectified by funding investments and subsidies for energy conservation as a distinct programme. The Group also felt that an energy conservation cess should be levied on an industry's consumption of petroleum products, coal & electricity. Other suggestions made by the Group covered the constitution of a central agency to monitor energy conservation in the transport sector, a separate unit in the State Electricity Boards to deal with conservation in agricultural pumpsets and awards for energy conservation. This would give an impetus for industry to invest in cogeneration systems It was also suggested that all large energy consumers should have energy conservation schemes as part of their R&D programmes. In short, the IMWG advocated the evolution of a package of fiscal incentives, disincentives and punitive measures as soon as possible to promote energy conservation.

The National Power Plan published in the same year, focussed on the environmental impacts of power projects and the evolution of methods to reduce these impacts.

The high level Advisory Board on Energy constituted by the Government of India and reporting directly to the Prime Minister, made an assessment of the energy sector in the country. The Board concluded that top priority was to be attached to meeting the energy requirements of households. In view of the scarce capital resources, better supply and demand management was identified to be a prerequisite to decrease energy intensity in the country. It was suggested that this decrease in energy intensity could be brought about by Government action in rectification of agricultural pumpsets, in the public sector industries, transportation etc. and through inter-fuel substitution in various sectors of the economy. The Board suggested that the ideal mix of oil, electricity and coal should be 42.1 per cent, 33 per cent and 24 9 per cent. The Board also suggested that a shift away from oil to natural gas and coal was desirable, especially in favour of natural gas given the problems of transportation of coal and decline in the quality of coal mined in the country. It advocated cross subsidies for the energy sector as a whole and cross financing among the different fuels. Thus, over the years there should be a movement away from oil to gas and to coal in the medium term and to renewable sources in the long term. This would imply moving from a centralized energy system to a decentralized one. The Board thus propounded a reduction of the energy intensity of the economy through a deliberate choice of technology and reallocation in the agriculture, industry and transport sectors without compromising on the objectives of economic growth.

The energy scene by the end of the 7th Plan was as follows. In spite of great strides in energy development, the per capita energy consumption is around 225 kg oil equivalent compared to about 5000 kg OE for Netherlands.

☐ The generating capacity by the end of 7th plan was 69082 MW. The total electricity generation in 1991-92 was about 312 billion kWh.

☐ The production of coal in 1991-92 was about 229 million tons.

☐ The production of crude oil in 1991-92 was 30.34 million tons and import was 24.00 million tons

☐ The current production of natural gas is about 16 billion m^3 per year.

The above description gives in brief, an overview of the energy planning process in the country since independence It can be seen that while a number of valid suggestions have been made over the years, only a few recommendations have actually found their way into the plans. There were some surprises too. The ABE report includes a detailed discussion on utilization of renewable sources of energy, especially biogas and solar energy There were no wind farms at that time and hence the potential of utilizing wind energy was not demonstrated on a large scale. In fact, except biogas, which was considered as the main source to combat deforestation, no other renewable energy source was considered seriously for contribution to the energy sector in the report.

5.2 Eighth plan

The following excerpts from the plan document serve to indicate the government's current policy in the energy sector (p.14, vol.1, Eighth Five Year Plan).

> "The physical infrastructure, particularly in the areas of energy, transport, communication and irrigation, has traditionally been provided by the public sector. Since the scale of

construction in these areas is very large and these are of direct and indirect benefit to large sections of society, the public sector will continue to play a dominant role in this area and will have the ultimate responsibility of meeting the demands. However, if private initiative comes forward to participate in creating such infrastructure like power plants, roads, bridges, medium and minor irrigation projects, social housing, industrial estates, on reasonable terms and with full protection of people's interests, such initiative must be positively encouraged".

"Among the main components of infrastructure, energy needs particular attention during the 8th plan mainly because of the fast growing demand, the limits of our internal sources of energy and implications for balances of payment. The medium term energy plan has to be seen only as a component of a long term plan where the strategies of fuel substitution and shifts from non-commercial sources of energy to commercial sources is clearly spelt out.

It is only in the perspective of such a long term plan that a view about priorities and relative emphasis on use of petroleum based energy will emerge and will have to be pursued right from now through the 8th plan. While planning for energy development, equal emphasis will have to be given to improving the performance of the existing plants by enforcing higher efficiency norms It should always be remembered that substantial improvement in the plant load factor can itself bring about sizeable additional electricity. Greater emphasis on developing non-conventional energy and on energy saving practices is also required".

"The goals in the energy sector, interalia, envisage elimination of power shortages in different parts of the country, achievement of a minimum hydel share of 40% in the total installed capacity by the end of the 9th plan, restraining the growth in consumption of petroleum products without hampering economic development, elimination of the flaring of associated natural gas, stepping up the levels of output of coal and lignite, promotion of cost-effective technologies for the development of renewable and non-conventional energy sources and enlargement of the coverage of Integrated Rural Energy Project (IREP)".

Several things become immediately apparent from the above objectives, as summarized below:

1 The government's major concern is with reducing the gap between supply and demand and with balance of payment situation being a major constraint.
2 Concepts like sustainable development, do not yet form the basis of planning.
3 Energy will continue to be in the public sector. Private sector participation in power generation is welcome but is not the primary goal.
4 While there is a clear target for hydel, (40% of installed capacity) policies of encouraging renewables, energy conservation, etc. do not get translated into specific goals.

Further insights into the energy policy can be obtained by taking a close look into the 8th Plan. The following table gives the outlay by major heads of development (p.57, vol.1, 8th Plan)

Rs. crores

Sl. No.	Head of Development	Centre			States	UTS	Total	8th Plan % to Total	7th Plan % to Total
		Budget Support	IEBR	Total					
I	Agriculture & Allied Activities$	12394 00	224 00	12618 00	42135 35	239 15	54992 50	12 67	14 27
II	Rural Development	24170 00	0 00	24170 00	10213 26	42 10	34425 36	7 93	5 01
III	Special Area Programmes	0 00	0 00	0 00	6750 16	0 00	6750 16	1 55	1 75
IV	Energy*	13136 00	53659 00	66795 00	47291 58	1474 51	115561 09	26 62	30 48
V	Industry & Minerals	9186 00	28353 00	37539 00	9284 89	97 86	46921 75	10 81	12 48
VI	Transport	8636 00	32341 00	40977 00	13786 58	1161 99	55925 57	12 88	12 76
VII	Communication	715 00	24382 00	25097 00	12 50	0 48	25109 98	5 78	3 60
VIII	Science & Technology	3739 00	200 00	3939 00	188 72	3 99	4131 71	0 95	1 13
IX	Ecology & Environment#	1200 00	0 00	1200 00	3654 12	55 82	4909 96	1 13	1 27
X	General Economic & General Services	1040 55	44 00	1084 55	5079 04	196 41	6360 00	1 47	0 94
XI	Social Services	29508 45	4937 00	34445 45	41588 76	2977 69	79011 90	18 20	16 31
	Grand Total	103725 00	144140 00	247865 00	179985 00	6250 00	434100 00	100 00	100 00

*Includes allocations for Integrated Rural Energy Planning Programme

$Includes Irrigation and Flood Control

#Includes allocations for Forestry and Wildlife

It is obvious from the above table that energy occupies a key position, having the highest percentage of the outlay

Within the energy sector, the outlays for different categories are as follows (Table 3.18, vol.1, 8th Plan).

Rs. crores

		Centre			State	UTs	Total
		Budget Support	IEBR*	Total			
1	Power	8902.00	22279.00	31181.00	46961.86	1445.88	79588.74
2	Petroleum	577.00	23473.00	24000.00	--	--	24000.00
3.	Coal & Lignite	2600.00	7907.00	10507 00	--	--	10507.00
4.	Non-conventional Sources of Energy	1107.00	0 00	1107.00	329 72	28.63	1465.35
	Total	13136.00	53659.00	66795 00	47291 58	1474.51	115561 09

*Internal and extra budgetary resources

Volume II of the plan gives more details of outlays in the energy sector. The outlays given are as follows

	Sector	Outlay (Rs. Crores)
1.	Petroleum Sector (excluding petro-chemicals)	24000.00
	Exploration	20000.00
	Production	4000.00
2.	Coal & Lignite	10507.00
	Coal India Ltd.	8520.00
	Singereni Collieries Ltd.	1000.00
	Neyveli Lignite Corp.	800.00
	Science & Technology	87.00
	Regional Exploration	25.00
	Environmental Measures & Subsidence Control	75.00
3.	Power	79589 32
	Generation	49424.15
	T&D	22280.75
	Rural Electrification	4000.00
	Renovation and Modernization	1776.44
	Miscellaneous	2107 98
4.	New and Renewable Sources of Energy.	
	Central Sector	857.00
	State Sector	305.11
5.	Energy Conservation	1000.00

While the figures for NRSE are different from those given in volume 1, the outlay for energy conservation has not been specified in vol. 1. The energy conservation and energy pricing related issues are discussed in greater detail here. The issues related to promotion of renewable energy resources are dealt in Chapter 3 and 7

5.3 Energy conservation

Energy conservation activities assumed importance after the 1st oil crisis in 1973-74, but no separate budget allocation was made initially in the 7th Plan. The PCRA was among the first government agencies to take up energy conservation schemes funded by the Oil Industry Development Board (OIDB) from 1976 onwards. A separate cell for energy conservation was created in the Department of Power (DOP) in 1986-87. The Energy Management Centre (EMC) was established in the DOP for promoting energy demand management and energy conservation in 1989-90.

Studies in six major energy intensive industries taken up by the Bureau of Industrial Costs and Prices (BICP) revealed considerable potential for saving energy. A special credit scheme was introduced through the Industrial Development Bank of India (IDBI) for financing energy conservation schemes in the industrial undertakings. All these measures had been sporadic, ad-hoc and uncoordinated, and hence the impact of these had been only marginal. Realizing this, a comprehensive National Energy Efficiency Programme (NEEP) is proposed in the 8th Plan. Targets of saving 5000 MW in the electricity sector and 6 million tons in the petroleum sector have been selected in the 8th Plan. The government proposes to include in NEEP components of policy package, financial arrangements including creation of a revolving fund, technical assistance, technology development, selective legislation and developing institutional capabilities. NEEP is supposed to cover all energy intensive sectors such as Industry, Agriculture, Transport, and domestic and commercial sectors. The scope and coverage of NEEP seem to be too broad and too diffuse to be effective. The plan document does not elaborate on how the government proposes to achieve the targets set for energy conservation. The financial allocation also seems to be incompatible with the broad scope and coverage of NEEP. Also, no specific institutional structure has been envisaged to.carry out NEEP.

5.4 Energy pricing in India

Energy prices in India have been viewed in a segmented manner dominated by social and political considerations in conflict with all other economic objectives. Thus, the energy prices continue to act as disincentives despite the recommendations by the various groups to the contrary. These opinions are summarized below.

> The basic recommendations of the Energy Survey of India Committee (1965) were with regard to the pricing of energy sources. The Committee felt that prices should reflect the relative scarcity of the fuel, with normal profits being allowed. With special reference to electricity, the Committee suggested

that the tariff policy should not reflect a payment for services rendered but rather should serve as an incentive to use electricity efficiently.

The Fuel Policy Committee defined the price structure for energy sources. Broadly, it recommended that prices should reflect the production cost of the energy source, taking into account at least a 10 per cent rate of return on the investment made. Prices should also reflect the relative scarcity of the energy source. Differential pricing for peak and off-peak hours was suggested. However, electricity supplied to the agricultural sector was to be at supply prices.

The IMWG felt that the pricing structure should be rationalized as the present trend of low prices promoted inefficiency in the use of energy and this high rate of growth of consumption led to an inadequate return on the capital investment made.

Such a situation would still be defensible had the benefits of the resultant subsidies reached the target population Unfortunately, an analysis of the pattern of energy consumption and the energy subsidies exposes the distortions that have set into the system to owing lack of an integrated approach to energy pricing that may also have promoted overall economic efficiency The specific issues in the pricing of different fuels are discussed below

Coal prices

☐ There is a glaring discrepancy observed in the present price structure of non-coking coal, whereby some of the inferior grades of coal are priced higher per unit of heat value as compared to superior grades of coal This distortion is particularly noticeable in case of coal from Singareni coalfields of Andhra Pradesh.

☐ There is no systematic or logical principle adopted for inter--grade price differentials. A rational pricing structure should have an in-built allowance to adequately compensate the consumers for using lower quality coal, which is not the case here.

- Finally, a uniform price is charged for coal within each grade (with widely varying heat value). This is based on the lowest UHV (in kcal/kg) in the specified range of each grade, with the result that it provides no incentive to coal producers to supply coal with higher heat value covered in the grade.
- Being a labour intensive sector, the costs of production depend upon labour management and productivity. The pithead prices, which are related to the cost of production, have an in-built inefficiency in that the cost of production are calculated with total disregard for the low output per manshift (OMS), especially in case of older mines. An analysis carried out for this purpose shows that if the productivity (OMS) in case of all the less efficient mines were to increase to a level of average OMS for the new more efficient mines, the cost reduction (on account of lower manpower costs) would be at least 30%.

Petroleum prices

The trends of domestic and imported crude oil prices show that the.

- Price of domestically produced crude oil in India was maintained below the international price upto 1985-86 Thereafter, following the slump in international oil prices the imported crude oil prices have been lower than the price of indigenous crude oil. However, the data for 1989-90 again show a reversal of this trend with the average c.i.f price of international crude oil being higher than that of domestic on-shore crude oil.
- The movement in indigenous crude oil prices is fairly independent of the behaviour of imported crude oil prices.
- There has been a consistent pattern which shows that the government has been taking an increasing share of sales revenue by increasing the rate of royalty and oil development cess components of the delivered price of crude oil at the refineries.

The above trend of events leads to the following general observation.

☐ Prices of petroleum products like LDO and Furnace oil are steeply increasing when compared with those of LPG, kerosene, HSD and naphtha for fertilizer use.

☐ Keeping in view the socio-economic considerations a differential pricing structure has been evolved whereby concessional rates for naphtha and furnace oil for fertilizer as against non-fertilizer uses are being charged for mass consumption purposes and SKO is sold at subsidized rates.

☐ In general, the trend in domestic prices of crude oil and petroleum products is affected by movement in their external levels only to a limited extent. However, the price adjustments are made in such a way as to either moderate or postpone the effect of sharp external inflationary trend or cross subsidize certain mass consumption items to protect the interest of certain consumers.

On the whole, the government has been guided by short term goals in making petroleum product price changes

Electricity tariffs

Electricity pricing in India lies within the purview of the SEBs. The Electricity (Supply) Act was amended in 1978 to make SEBs commercially viable and to earn a net rate of return on their investments. The amendment to the Act in 1980 specified that the SEBs should earn a net return of 3 per cent on net fixed assets as at the beginning of the financial year, after payment of interest and provisions for depreciation. In practice, however, none of the state governments impose a mandatory rate of return on the SEBs and most of the SEBs in the past years have been unable to achieve the prescribed rate of return of 3 per cent.

Pricing of electricity by the SEBs have generally been based on the principle of recovering average cost of supply. A policy of differential pricing is followed in the supply of power to different consumer categories. Tariffs are often weighed more by social and political considerations rather than financial and economic efficiency objectives and therefore the tariffs for some consumer categories are set at a rate even lower than the average cost of generation and supply.

In view of the rising power shortages in the country and the financial constraints faced by the central and state governments, it is imperative that the SEBs must rationalize their tariffs to generate sufficient resources to finance the additional investments required by the increased growth rates in the demand for electricity The existing capital structure of the SEBs is entirely debt based. There is no equity contribution from the state governments and the only equity available is reserves, surpluses and consumer contribution towards cost of capital assets and grants and subventions from the government towards capital assets. With the rising cost of borrowed capital the SEBs should aim at generating at least 20 per cent of the total capital expenditure in any year as internal resources.

Prices based on the 'accounting approach' are inadequate as signalling devices and the appropriate signals (i e prices) should be related to the marginal (i.e incremental) costs of meeting additional consumption.

5.5 Potential, limitations and constraints

The two major concerns of the government in the energy sector are i) meeting the rising demand of power and ii) reducing the oil imports so as to limit the balance of payments situation It is also apparent that the government does not have a coherent, rational energy policy leading to sustainable development, and that if the current policies of the government are continued, there is no hope of meeting either the power needs or energy needs of the growing economy. With 65% of all electricity generated coming from coal thermal plants, the associated environmental pollution would be tremendous. It is clear that if care is not taken at present, the economy would fall into the vicious circle of underdevelopment and debt trap.

Alternative strategies for sustainable development do exist, however, in principle. These depend heavily on energy conservation and renewable energy utilization. The potential for these is also significant. There is scope for reducing 20-30% in energy consumption in industries, agricultural pumpsets, domestic appliances etc Hence, it is apparent that by suitable utilization of energy conservation methods and renewable energy technologies, it should be possible to achieve the goals of sustainable development, viz. reduction of energy consumption and reduction in emissions all around. The major constraints for implementing such policies are i) availability of technology ii) availability of capital iii) institutional constraints and iv) pricing constraints.

CHAPTER 6

Alternative strategies for conventional energy use

6.1 Introduction

The current strategies for energy of development still result in significant energy shortages. These shortages are associated with inefficiencies in consumption. Hence, despite low per capital consumption levels, there are significant adverse environmental impacts. This requires alternative development strategies for the country. The effects of the following two strategies on the energy situation in the country are examined:

1 Improving the efficiency of energy production, conversion and use; management of energy demand and encouraging technology/process changes;

2 Moving towards more environmentally benign energy forms i.e. the greater use of renewable energy resources.

These strategies form mutually exclusive ~~measures~~ and this chapter deals with the measures and the impact of improving the efficiency of energy use. Chapter 7 deals with the second strategy

The costs associated with various development strategies to the year 2009/10 include:

- ☐ direct economic costs associated with the production and supply of various energy sources;
- ☐ direct measures, and
- ☐ environmental costs associated with energy supply and demand management.

Thus the model uses an "expanded" economic approach since in the evaluation of strategies, costs include capital and operating costs and the costs of some environmental and social impacts of energy choices.

Energy supply measures for the following sectors have been costed: coal, oil, natural gas, hydropower, nuclear power, energy conservation, renewable options such as windfarms and small hydel projects. Shortages of oil and coal are valued at border prices as these would need to be imported. Lower bound estimates of the value of power shortages are obtained by estimating the costs involved in having standby generation. Energy savings from conservation measures are valued at border prices, wherever this results in a change in the net fuel imports, and at economic prices, where they are not. Depletion premiums have not been estimated.

Environmental costing employed indirect techniques involving the use of control costs (or cost of damage abatement approach), cost of damage approach, and the use of reclamation costs and rehabilitation costs. This costing [illegible] only the following [illegible] have been considered

In evaluating the current government strategy demand side investments are used as reference level and only supply side investments are considered. For the alternative strategies, incremental investment requirements for supply and energy demand measures over the current government strategy are taken into account.

6.2 BAU strategy

Owing to the fact that the demand side investments in the BAU strategy are made as the reference level, only supply side investments are presented below.

Economic costs associated with the BAU strategy, under a 5% per annum GDP growth assumption, are summarized in Table 6.2 1 Total investment for the strategy till 2009/10 is estimated at Rs. 3179.2 billion or an annual commitment of Rs 159 billion

It is assumed that various types of consumers will install and use standby dg (diesel generator) sets to mitigate the effects of power shortages. The capital investment requirement norms for various types of energy supply projects, are used for computing economic costs for all development strategies.

The major cost components are power supply (55.3%), hydrocarbon exploration and field development (18.8%), and fuel imports (13.2%). Costs incurred directly in foreign exchange (for fuel imports alone) are anticipated to rise to Rs. 418.5 billion

Table 6.2.1. Economic costs of energy supply in 2009/10 under the BAU strategy (Rs. million, 90/91 prices).

	BAU
Total investment	3179196
Coal mining	194562
Lignite mining	12078
Hydrocarbon exploration	497610
Hydrocarbon field development	98586
Refining	49122
LPG extraction	3960
Natural gas pipelines	
- on land	34776
- offshore	24516
Power supply	1758276
Power shortages	87246
Net fuel imports	418464
- Coal	41310
- Crude oil	168750
- Refined products	208404

80532

Investment in natural gas pipelines are relatively low as compared to the policy decision of expanding the network and increasing utilization of gas

The high investments in the hydrocarbon exploration and development as well as in power supply indicate the payoffs from these sectors would be high.

Coal imports refer to import of high quality coking coal for the iron and steel sector.

6.3 Alternative strategies

Strategy I: Energy efficiency improvements and conservation

Conservation of energy is important both from energy and environmental considerations. While these are reason enough to make conservation mandatory, further justification can be provided by way of its direct implications on increasing the availability of energy to a larger section of the population as well as on reducing foreign exchange outflows. This section analyses specific energy conservation measures that can be implemented, both on the demand and supply fronts, in the next 20 years along with estimates of the investment requirements of doing so.

Assumptions on demand side

The commercial fuel mix in 2009/10 under the BAU strategy was assumed to be 53:29:9:9 for coal:oil:gas:electricity with a energy equivalent to 601 mt-oe. The demand side investments for the BAU strategy are chosen as the reference level, and therefore only incremental investments for the set of demand management measures that comprise the alternative strategies are included. Some general assumptions for the economic analysis are as follows:

Domestic sector. Efficiency improvements in this sector can take place in the following activities : cooking, lighting, water heating and other electrical appliances.

(a) **Cooking:** A 5% improvement in the present average efficiency of LPG stoves by the turn of the century and a 10% improvement by the year 2009-10 is assumed. In case of kerosene stoves and cookstoves using soft coke an efficiency improvement of 10% has been considered.

(b) **Lighting:** For lighting purposes, the option of replacing incandescent bulbs with fluorescent tubes has been considered. The case where all additional incandescent bulb connections in the households as per the BAU-scenario will get replaced by half as many fluorescent connections has been considered[1] The comparative economic analysis of fluorescent and incandescent is carried out by taking the average market price of installing the two types of connections The price of each of the component parts and its operating life is given in Table 6.3.1. The cost of electricity is taken to be Rs. 1.44/kWh.

The economic analysis of energy efficient lighting yields a national electricity saving of 2.85 TWh per annum equal to Rs. 4503 million.

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[1] This is because the lumen output of one 40 watt 4 feet long fluorescent tube is approximately the same as that of 2 incandescent bulbs of 100 watts each. If, however, a 40 watt fluorescent tube was used to replace two 60 watts incandescent bulbs, the lumen output would actually increase [TERI (1990)]

Table 6.3.1. Assumptions regarding the market price and operating life of fluorescent and incandescent.

	Market price (Rs./unit)	Operating life (years)
Fluorescent		
- Holder	39.6	15
- Tube	39.2	2[1]
- Choke	75.6	5
Incandescent		
- Holder	30.6	10
- Bulb	9.0	0 4[1]

[1] These are estimated by assuming the average life of a fluorescent lamp to be 5000 hours, incandescent bulb as 1000 hours and the average daily use to be about 7 hours

(c) **Other electrical appliances:** The Tata Energy Research Institute recently carried out a survey on the efficiency (energy) of currently used domestic appliances [TERI (1991)] Based on the results of this study, a 20% efficiency improvement over the present levels for air-conditioners has been assumed through proper maintenance of the air-conditioning system alone.

In the case of refrigerators, an efficiency improvement of 30% resulting from minor maintenance and regular defrosting is assumed by the year 1999-2000. From 1999-2000 to 2009-10 it has been assumed that 25% of the old stock will get replaced by more energy efficient refrigerators. For the balance 75% regular maintenance will result in a 30% conservation of energy For improved refrigerators, the market prices of the old and new models of refrigerators are taken as Rs. 5994 and Rs 7506 respectively, with the mean operating life of 20 years. In case of both the models, annual maintenance costs are assumed to be 1% of the capital cost. Net annual savings are estimated at Rs. 5194 million with the corresponding savings of 4.51 TWh.

A small efficiency improvement of 5% in energy consumption of ceiling fans is assumed to be achievable by minor maintenance measures such as regular greasing etc.

The investments that would be required for implementing the above mentioned measures are estimated in the range of Rs. 66600 million.

Transport sector

The measures likely to result in reduced energy consumption levels in the transport sector are:

1 The road user cost study conducted by the Government of India estimated 10% fuel efficiency improvements due to various measures adopted for improving road conditions. The range of road improvement measures include low grade section to be upgraded and widened, single lane road to be widened and strengthened, four-laning and two-laning of some sections, exclusive lanes and grade separation of traffic, removal of encroachments on roads and pavements, etc. Road improvements also bring other benefits like improvement in tyre life, engine life, etc., which is not accounted for in the present study. The investments are phased out at the rate of 40%, 30%, 20% and 10% of a total of Rs. 157 billion for the years 1994/95, 1999/00, 2004/05 and 2009/10 respectively O&M costs are assumed at 5% of the capital cost. Annualized costs are estimated at Rs. 2.12/kgoe.

2 A shift from road transportation to rail transportation for both passenger and freight traffic. The National Transport Policy Committee of the Government of India had recommended a rail-road mix of 40:60 in passenger transportation and 72.28 for freight transportation. It has been assumed that this mix would be achieved by the year 2009-10 from the present levels of 21:79 for passenger transportation and 51:49 for freight transportation For this option, the investment (Rs. 900 billion) is assumed to be phased similar to the strategy of road improvements. The life of the system is assumed to be 35 years and O&M cost at 2.5%. Saving are estimated at around 12 mtoe with annualized costs of Rs. 13/kgoe saved.

3 Introduction of more efficient buses (termed as urban bus) for intra-city passenger transportation could lead to an efficiency improvement of 10%. The urban bus has a design capacity of 60 and crush loading of 90. It has low floor height with a new and more efficient engine. It is fuel efficient and, at lower speeds, emits less pollutants. the

urban bus is faster than the standard bus under urban conditions due to better acceleration. Its weight is less because of the use of lighter material. All existing buses are assumed to be phased out with the introduction of urban buses. The additional capital cost is taken as Rs. 9 million, O&M at 5% of the capital and a life of 20 years. This yields annualized costs of Rs. 2.07/kgoe saved.

4 At present, only 2 cities (Bombay and Calcutta) in India have urban rail transport system. Urban rail transport systems lead to a reduction in energy consumption and associated emissions reduction. A detailed feasibility report prepared by Rail India Technical and Economic Services (RITES) for the city of Delhi forms the basis for the analysis. Urban rail transport (metro) in Madras and Delhi and seven cities with populations between 2 and 8 million has been recommended since the metro in low density corridors is deemed unfeasible. The metro option has an average investment of Rs. 23.4 billion each, providing a capacity of 20 billion person kilometre (BPKM) annually. The phasing of the project would be similar to that for road improvements. Interest during construction (IDC) has been included at 12%. It is assumed that metro systems start functioning from the year 2000/01 and hence the swing effect i.e. shift from road transport modes to metro will be observed only after 2000/01. Based on the pkm the metro system would satisfy, it is assumed that it would displace 10% of cars, 10% of three wheelers, 45% of two wheelers and 35% of buses in each of the cities. The life of the system is assumed to be 35 years and O&M costs are placed at 5% of the capital cost. The fuel consumption of the metro system is assumed to be 9 watt-hours per pkm [8 kcal/pkm (30 kcal/pkm taking in to account the generation and T&D efficiencies)] as against 92 kcal/pkm for a bus. Annualized costs are Rs. 1.91/kgoe saved indicating positive benefit from the scheme.

Table 6.3.2. Annualized cost per unit of energy saved in the transport sector.

	Fuel saving (mtoe)	Rs./(kgoe saved)
Urban buses	3.297	2.07
Road improvements	8.107	2.12
Shift from road to rail	12.091	1.30
Metro system	2.719	-1 91

Note: - implies overall investment savings over BAU

Industrial sector

Energy conservation measures have been analyzed for three industries (steel, cement, chemicals and petrochemicals). The assumptions made for this sector based on discussions with industry experts are outlined below. O&M costs for these three industries are assumed as 2.5% of capital costs and life as twenty years.

(a) **Steel:** Indian integrated steel plants tend to consume nearly 60% more energy than their counterparts abroad. A major part of the energy consumption in the steel sector is at the blast furnace/crude steel making stage. Typically energy conservation/productivity improvements can result from.

- ☐ improved control over-burden preparation
- ☐ improved process control
- ☐ injection of pulverised fuel to substitute coke
- ☐ better energy recovery from top gas and from using the high top pressures employed in modern furnaces to drive the turbine
- ☐ longer campaign life through improved refractory and cooling systems
- ☐ alternative form of heat energy etc.

Table 6.3.3. Comparison of energy efficiency of Indian plants vis-a-vis other countries.

	Energy consumption in Gcal per tonne of crude steel	Coke rate (tonne/tonne)
Italy	4.2	463
Japan	4.5	484
U.K.	5.6	557
Brazil	5.7	480
India	9.8-13.7	735-1188

Source: GOI (1989a).

A study carried out by the Bureau of Industrial Costs and Prices on particular steel plants points out the possibility of reducing energy consumption in these plants from the present level of 7.2 to 8 Gcal/metric tonne of crude steel to a level of 5.5 Gcal/metric tonne. Extrapolating this for other steel plants, it is estimated that the investments that would be required for achieving this level of efficiency improvements would be in the range of Rs 197906.4 million for integrated steel plants with associated annualized costs of Rs. 1.9-8/kgoe saved.

(b) **Cement:** In the case of cement industry it has been assumed that the remaining wet process capacity in cement production under BAU would be completely replaced by the dry process technology. An additional 10% reduction in the specific consumption norms for the dry process by close circuiting the cement mill by installation of high efficiency separator, X-Ray analyzer for speedy process control and replacement of low efficiency fans by high efficiency ones have been considered. The investment requirements for doing the above have been estimated at Rs. 13806 million. Annualized costs are estimated at Rs. 0.54/kgoe saved.

(c) **Chemicals and petro-chemicals:** The potential for energy conservation have been based on a case study of the National Organic Chemical Industry Ltd. (NOCIL). The company succeeded in achieving specific fuel consumption levels of 0.947 tonnes of naphtha equivalent fuel per tonne of output against the prevailing level of 1.257 tonne per tonne of output through specific energy conservation measures. It has been estimated that a minimum reduction of 20% is absolutely essential for firms to be financially viable. To achieve this saving an investment of Rs. 8694 million would be required for the sector. The major non-organic chemicals wherein energy conservation could be effective are soda ash and caustic soda. To achieve an overall energy savings of 30% in this sector, an investment requirement of Rs. 2372-4 million has been estimated. Costs (annualized) per kgoe saved are estimated at Rs. 2.16.

Agriculture sector

Irrigation is one of the major end-uses of energy in the agricultural sector. Table 6.3.4 summarizes the expected savings from the various retrofit measures that have been considered and the distribution of pumpsets on which each of these measures would be applied. The investments that would be required for implementing these retrofit measures are of the order of Rs.104166 million. Further, an option of a more efficient irrigation practice has also been considered, i.e. the use of drip irrigation for crops such as sugarcane, cotton and oilseeds and sprinkler irrigation for maize and grain; with application efficiency of 95% and 85%, respectively, against present application efficiencies of less than 50%. Investments required for installing these irrigation systems are approximately Rs. 203562 million.

Table 6.3.4. Expected savings from different retrofit procedures[a].

Retrofit measures	Per cent of pumpsets	Expected savings (%)
Involving subsystem components		
1. Replacement of foot valve and suction pipeline (R_1)	30	8-12
2. Replacement of foot valve, suction, and delivery pipeline (R_2)	40	10-20
Involving subsystems		
3. R_2 + replacement of pump (R_3)	10	20-40
Involving entire system		
4. R_3 + change of motor (i.e.complete replacement)(R_4)	20	30-50

[a] Abridged from Patel 1988.

The cost of replacing the footvalve and suction pipeline is assumed to be Rs. 576 (Rs. 828 with delivery line included) per pump-set and the life of both 5 years The cost of replacing the pump and the motor is assumed to be Rs. 2736 and Rs. 6840, respectively, with associated lifes of 7 and 15 years, respectively.

These assumptions yield annualized costs per kgoe saved as Rs. 0.54 for retrofitting pumps only and Rs. 7.02 for retrofitting pumps with a penetration of drip and sprinkler irrigation system

Assumptions for the supply side

The major improvements considered in the performance of the energy supply industries are·

1 a reduction in T & D losses, from 23% to 18%.

2) the establishment of non-coking coal washeries to reduce ash content of steam grade coal used for thermal power generation.

No significant improvements in the production efficiencies of coal and oil subsectors are assumed.

T & D losses are assumed to reduce from the present level of 23%, to 22.5% in 1999/2000, to 20.5% by 2004/05 and to 18% by 2009/10. Further, it is assumed that washing non-coking coal reduces the ash content by about 7%. With this, the performance of TPS is enhanced due to (a) an improvement in the plant heat rate from 2336 kcal/kWh to 2304 kcal/kWh, (b) a reduction in auxiliary consumption levels from 10% of gross generation to 9.58%, (c) a reduction in coal utilization from 0.65 kg/kWh of gross generation to 0.44 kg/kWh (even if washery rejects are 20% of the coal feed, the input coal requirements are 0.55 kg/kWh), and (d) a reduction in the oil use from 15 ml/kWh to 10 ml/kWh.

Although the actual phasing of investment is not accounted for in the economic analysis, gestation periods are used to compute the interest during construction (IDC) at a social discount rate of 12% per annum. Fixed O&M costs (as a percentage of capital investment plus IDC) are assumed as follows :

1 1% for large hydro projects;
2 2.5% for coal based TPS units, using both washed and unwashed coals;
3 2% for GT/CCP units;
4 2.5% for nuclear power stations;
5 5% for LPG extraction plants,
6 7.5% for natural gas pipelines, both onland and offshore; and
7 10% for exploratory drilling and oil/gas field developmental activities

Capital costs are annuitized over the economic lifetimes of these assets. Table 6.3.5 lists the gestation periods, IDC factors, economic life times and capital recovery factors (CRF) for various energy supply infrastructure requirements

Table 6.3.5. IDC factors* and CRF for energy supply infrastructure.

	Gestation period (years)	IDC factor*	Economic life (years)	CRF
Power Plant				
- Hydro	8	1.5036	50	0.1204
- TPS	6	1.3382	30	0.1241
- GT/CCP	3	1.1236	30	0.1241
- Nuclear	12	1.8983	30	0.1241
Refinery				
- with FCC	6	1.3382	30	0.1241
- with HCU	6	1.3382	30	0.1241
LPG Extraction	2	1.06	30	0.1241
Coal Mining				
- OC	5	1.2625	35	0.1223
- UG	8	1.5036	35	0.1223
Gas Pipelines				
- On land	2	1.06	30	0.1241
- Offshore	2	1.06	30	0.1241

* Ratio of IDC plus capital investment to capital investment

On the basis of the sectoral assumptions listed above, the annualized incremental requirements (over BAU) are listed in Table 6.3.6

Table 6.3.6. Annualized incremental requirements for alternative strategies (million Rs.).

Domestic sector	21
Industrial sector	31550
Transport sector	34621
Agricultural sector*	33998
Total	100190

Cost figure includes drip and sprinkler irrigation systems (essentially water conserving measures) comprising 95% of the costs and retrofitting pumps which comprise the remaining 5% of the costs.

6.4 Demand/supply situation from the conservation strategy

Significant reductions can be affected in energy demand through measures suggested above. While no clear pattern of savings emerges, the net savings across sectors is presented in Table 6.4.1.

Table 6.4.1. Energy savings.

	Electricity BAU (GWh)	Strategy I % change	Coal BAU (MT)	Firewood Strategy I % change	BAU (MT)	Strategy I % change
1994-95	304175	14.41	314.78	12.17	146.99	4.41
1999-00	384661	12.44	390.40	18.25	159.02	5.89
2004-05	501113	11.15	492.01	17.02	171.24	7.41
2009-10	672593	7.64	647.51	16.11	184.36	8.93

Table 6.4.1. Energy savings (cont.)

	Oil BAU (MT)	Strategy I % change	Natural Gas BAU (MCM)	Strategy I % change
1994-95	80.14	25.03	23327.31	10.58
1999-00	104.82	20.40	36747.92	11.00
2004-05	134.33	24.03	46803.97	9.40
2009-10	174.46	25.98	62596.58	0.16

Power sector

Electricity savings are seen to be much larger in the short-term as compared to the long-term. This is because in the long-term a larger shift to electrified routes for transportation has been assumed The largest savings potential is in the northern region followed by the eastern region up to the turn of the century and the southern region in the next decade.

With improvements in the power sector under the conservation strategy, the required increases in generation capacity are considerably lower than in the BAU strategy of development. Capacity additions in successive five-year intervals from 1990/91 to 2009/10 are given in Table 6.4.2. It is assumed that coal will be washed for power generation in Northern, Western and Southern Regions only -- regions where coal is transported over relatively long distances by rail.

Even with lower capacity additions in strategy I as compared to BAU, the projected power shortages (both in terms of peak and energy) are rather small.

Table 6.4.2. Power Generating Capacity Additions (MW) - Strategy I.

	April 1990 to March 1995	April 1995 to March 2000	April 2000 to March 2005	April 2005 to March 2010
Hydro	5957	6500	8000	10500
TPS	6590	8950	11800	10850
TPS/Washery	210	1050	4200	14650
GT/CCP	5000	4000	2490	6700
Nuclear	940	940	2440	3878
Total	18697	21440	28930	46578

Table 6.4.3. Peak Demand and Energy Shortages (Strategy I)

	1994/95	1999/00	2004/05	2009/10
% Peak shortage	3	4	5	4
% Energy shortage	~	~	2	2

~ : < 0.5%

In the conservation strategy, investment levels in the power sector are considerably lower than in the BAU strategy, even with the inclusion of washery costs (Table 6.4.4). Capital costs of a washery are estimated at Rs. 64.26 million/mtpa and a capacity utilization factor of 90% is assumed. The strategy assumes that one-third of the T & D loss reduction in any year will be technical losses -- the rest will be due to improved billing procedures, better metering etc., which entail little investment. The fuel inputs required for power generation in both the strategies are incorporated in the energy demand projections.

Table 6.4.4. Investment requirements in the Power Sector.

(Rs. million)

	1990/91 to 1994/95	1995/96 to 1999/00	2000/01 to 2004/05	2005/06 to 2009/10
Washeries	45.18	225.54	901.98	3146 22
Despatchable generation tech	209772	261216	375966	625428
T & D Systems expansion	139842	174150	250650	416952
T & D Loss reduction	0	4914	23994	42606
Total	349650	440514	651510	1088122

Coal and lignite situation

The indigenous production of coking and non-coking coals as well as lignite remain the same as in the BAU strategy, and so do investment requirements (see Chapter 2). However, the demand, both for power generation and other uses is considerably reduced in the conservation strategy. If production levels are maintained as in the BAU strategy, there will be an overall surplus of non-coking coal. Coal savings are seen to be fluctuating -- increasing from 12% in 1994/95 to 18% in 1999/2000 but reducing again to 16% in the year 2009/10. National imports of coal are negative, indicating a surplus domestic availability of 20.00, 68.47, 88 and 79.16 Mt per year for the years 1994/95, 1999/2000, 1004/05, and 2009/10 respectively.

Oil situation

In the conservation strategy, both the indigenous crude oil production and refining capacity and complexity remain the same as in the BAU strategy; so do investment levels. However, as the demands for various products are relatively lower in the conservation strategy, India's self-sufficiency in refining capability increases. Refining capacity (as a percentage of demand), increases to nearly 100% by 2009/10. However, as the capacity utilization of refineries is assumed to be 90% (as in the BAU strategy) and refinery losses at 6%, total refinery production will be considerably lower than demand. In the case of oil consumption very significant savings in the range of 20 to 25% are noticed under the conservation strategy.

Table 6.4.5. Oil supply situation.

(MT per annum)

	Strategy I 1994/95	1999/00	2004/05	2009/10
Refining Capacity	61.8	81.6	105.3	138.4
Crude Throughput	55.6	73.4	94.7	124.5
Refinery Output				
-Total	52.3	69.0	89.0	117.1
-Light Distillates	10.9	14.7	19.3	25.8
-Middle Distillates	29.1	39.1	51 1	68.0
Heavy Ends	12.3	15.2	18 6	23.4
Net Imports				
-Crude	20 1	30.2	41.4	54.0
-Light Distillates	0.4	-1.3	-3 2	-5.5
-Middle Distillates	7.7	16 4	16.3	15.0
-Heavy Ends	3.9	4 7	6 8	11.9

Gas situation

In the conservation strategy, the demand for natural gas is lower than in the BAU strategy -- and so is gas production from free gas fields. The production of associated gas remains as in the BAU strategy. All natural gas requirements will be met through indigenous sources

Table 6.4.6 gives the capital investment requirement for pipelines on land and off-shore for the strategy.

Table 6.4.6. Investment for Natural Gas Pipelines - Strategy 1.

	1990/91 to 1994/95	1995/96 to 1999/00	2000/01 to 2004/05	2005/06 to 2009/10
Pipelines (Rs. million)				
-onland	1725	2108	1727	3576
-offshore	1294	740	1002	2530
-Total	3019	2848	2729	6106

A sectoral picture of energy savings is given in table 6.4.7 below. The largest savings potential is seen to be in agricultural sector for electricity followed by the domestic sector. Coal savings in the range of 15-20% are possible in both the major consuming sectors of power and industry. The maximum reduction in oil consumption is noticed in the transportation sector which has largely been due to the modal shifts assumed

Table 6.4.7. Energy savings for 2009-10.

	BAU	Strategy I	% Change Strategy I
ELECTRICITY (TWh)			
Industry	359.4	342.5	4.68
Transport	13.0	32.7	-151.55
Domestic	94.9	86.1	9 30
Agriculture	138.0	97.7	29.20
TOTAL	672.6	621.2	7.64
COAL (MT)			
Industry	184.9	148.8	19.49
Power	389.3	324.4	16.66
Transport	3.8	11.4	-198.21
Domestic	3 3	3.0	9.20
TOTAL	645.9	541.8	16.11
OIL (MT)			
Industry	33.8	30.7	8.99
Power	8.8	6.8	22.76
Transport	89.4	54.8	38.64
Domestic	21.7	19.5	10.00
Agriculture	9.6	8.1	15.00
TOTAL	174.5	129.1	25.98
Natural Gas (BCM)			
Industry	23.9	22.0	8.02
Power	38.7	40.5	-4.70
Total	62.6	62.5	0.16
FIREWOOD (MT)			
Rural	153.3	153.3	0.00
TOTAL	184.4	184.4	0.00

In the conservation strategy, where washing of non-coking coal for use in TPS units, and T&D loss reduction are the major measures to enhance, the efficiency of the energy supply industry, the total economic costs are estimated at Rs. 2518 billion. These costs imply a reduction by 20.8% from the corresponding BAU levels. This substantial reduction is due also to the fact that energy conservation measures are affected on the demand side - which in turn reduces the need to invest in energy supply projects.

Table 6.4.8. Changes in economic costs of energy supply in the alternative strategies.

Alternative	Strategy I
Percent reduction from BAU strategy	
Total	20.8
Hydrocarbon field development	0.05
Natural gas pipelines	
- on land	0.2
- offshore	0.15
Power supply	17.2
Power shortages	53.4
Net fuel imports	74.8
- Coal	366.6
- Crude oil	0
- Refined products	77.5
Environ costs	17.3%
Memo item	
Total costs (Rs. million)	2518272
Coal washing Costs (Rs. million)	662

Note: Coal washing is treated as a production cost of energy supply and not as an environmental cost.

Power supply costs reduce in strategy I from BAU levels (since smaller capacity additions are required).

Perhaps the greatest differences are observed with regard to net fuel import bills. In strategy I, the reduction of foreign exchange requirements for fuel imports are substantial -- about 75% from the BAU level and the net fuel import bill reduces to Rs. 106 billion. The relative effects on the net fuel import bills clearly indicates the need to implement conservation measures both on energy supply and demand sides

CHAPTER 7

Alternative strategy II: use of renewable technologies

7.1 Introduction

As in indicated in Chapter 6, the current strategies for energy of development will result in significant energy shortages. Moving towards more environmentally benign energy forms which may be more efficient to use (for instance, natural gas) or renewable in nature (such as wind energy) is one attractive solution.

Financial commitment for increased utilization of renewables poses, and will continue to pose, the most serious hurdle in the context of India. As Grubb (1990) points out,

> it is implausible under almost any technical outlook that the costs of collecting and converting diffuse renewables can compete with the costs of drilling a hole in the ground and letting oil or gas well up.

There appears to be some dispute on the overall economics of renewable energy technologies (RETs) for several applications in India with divergent views on the estimates of cost and the related views Part of this arises from the traditional supply orientation in energy planning in the past, which has shown emphasis on development of the power, coal and hydrocarbons supply industries without adequate regard to specific end uses which determine the total demand for these and other forms of energy. Not accounting for any renewable energy technologies nor viewing demand in the form of specific end uses is still common among those responsible for formulating energy plans in India. The total social cost of supply of conventional fuels, in addition, is often underestimated.[1]

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[1] Proponents of renewable energy technologies, on the other hand, often assume ideal conditions in the operation, maintenance and performance of renewable energy devices Here, we attempt to include all the costs of conventional energy supply in relation to alternative forms of non-conventional energy supply Operational, organizational, and other factors which might actually reduce the merit of renewable energy technologies in the field is accounted for in subsequent sections

As pointed out in Chapter 6, in the analysis presented here we attempt to internalize many of the costs associated with conventional energy technologies. The costs associated with various conventional energy development strategies to the include:

☐ direct economic costs associated with the production and supply of various energy sources;
☐ direct environmental control measures; and
☐ environmental costs associated with energy supply and demand management.

To reiterate what has been said in Chapter 6, the costing attempts to use an "expanded" economic approach since in the evaluation of strategies, costs include capital and operating costs and the costs of some environmental and social impacts of energy choices. (see section 1 of Chapter 6 for details of the costs included). The alternative energy options for meeting energy demands and augmenting energy supply using renewables is worked out after including these costs. Prior to this, however, a critical appraisal of the status of different renewable energy technologies is required in order to project the role they can play in the Indian energy system.

Experience with RETs and renewable programme prioritization

The programme started on a significant scale with the establishment of the Department of Non-conventional Energy Sources (now referred to as the Ministry of Non-conventional Energy Sources, MoNES) in 1982. Started as a modest programme with an annual outlay of about Rs 4.3 crores in 1980/81, by the end of the 6th Plan period (1985) the annual allocation of the MoNES increased to over Rs 33 7 crores The 7th Plan (1985-90) continued with the increase in funding for these technologies. The first year allocation of the 7th Plan (of Rs 88.7 crores) itself touched the total outlay of the five years of the 6th plan (1980-85) and the allocation in the renewable energy sector stabilized to about Rs 130 crore annually. In spite of the sharp increase in funding for the renewable technologies, the fund allocation has remained small in comparison to the total outlay for the energy sector as a whole. Between April, 1980 and March, 1992, the total cumulative Government expenditure in the renewable sector totalled to Rs 1,155 crores. In comparison, the Government invested over Rs 81,200 crores in the power sector, over Rs 33,500 crores in the petroleum sector and about Rs 15,850 crores in the coal sector.[2]

A decade of the renewable energy programme in India has witnessed many of the new technologies being forcefully promoted as solutions to the energy problems before the technology reached the level of maturity warranting such an effort. Aggressive promotion led to unreasonably high expectations from RETs and the promotional effort, either explicitly or implicitly, gave the impression that these technologies were the answer to all the energy problems of the country. Ironically, today those efforts have resulted in the greatest barriers to the introduction of these technologies -- there is widespread feeling among those associated with the energy planning process that RETs and their possible role is grossly overrated.[3] Therefore, now when some of the renewable technologies have actually achieved some level of maturity, proponents of these technologies find few planners with faith in their viability. Clearly, unambiguous statements of the constraints and the strengths associated with different renewable technologies is called for in order to regain credibility for these technologies. Substantial efforts need to be devoted to a serious assessment of what current technology is able to achieve and to arrive at a realistic estimate of the potential for these technologies within the context of the overall energy system.

Unfortunately, there seems to be inadequate appreciation of the reasons for the indifferent performance of some renewable technologies by those managing these projects. Attempt to seek massive funding for demonstrating an immature technology, as has been done in the past, invariably leads to a significant loss of credibility for other mature technologies Clearly, for the renewable programme to make a significant contribution to the energy scene in India, firm priorities must be set. Technologies which are mature, reliable and cost effective must be promoted with vigour.

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[2] Despite the relatively small investment in the renewable sector in the first decade of its existence, the trends in the investment appear encouraging Using the investments of 1980/81 as the base, the investment in 1988/89 are higher by a factor of over 30 while those in the other energy component sectors range between 3 to 4 times that of the levels of 1980/81

[3] This situation is not unique to India and an excellent summary of the perceptions regarding the role and the relevance of renewables can be found in Grubb (1990)

As implemented today, the renewable programme is extremely diffuse and seems to be moving in too many direction. With this in view, we believe that the renewable energy programme should focus on

1 large-scale utilization of wind electric converters in windfarms and small hydro power development for power generation using renewables,
2 immediate commercialization of solar hot water systems and solar cookers with gradual withdrawal of Government subsidy linked to rationalization of prices for electricity and LPG respectively, as these technologies have reached a level of maturity which merits such a promotional effort.

In addition to this those responsible for the renewable energy programme should consider

3 the withdrawal from the promotion of solar photovoltaics except for uses (such as education and health care uses in rural areas) with substantial social benefits,
4 intensifying efforts at further technology development for biogas and cookstoves. In addition, critical re-appraisal of the implementation strategies for biogas and improved cookstoves to look at the purpose and the extent of intervention and the relevance of the respective technologies to these. The possibility of an alternate delivery system for both these technologies (including removing the involvement of the Bank and, possibly leaving the transformation of the implementation to a commercial activity in the NGO sector),
5 undertaking the development of a programme of research and technology development for attractive technologies with high potential such as water pumping windmills, gasifiers, biomass based stirling engines, solar ponds, solar thermal cooling technologies based on evacuated tubular collectors, etc., and,
6 developing capabilities for planning and management of decentralized energy plan.

In the context of limited financial resource availability, a clear prioritization of renewable energy technologies based on cost effectiveness appears important for this sector to make any significant impact. With this in view, we first estimate the likely impact of RETs on the energy system in

India. Thereafter, we discuss in detail the measures and the strategies required for the rapid deployment and the commercialization of these technologies.

Supply side renewable options

The major changes on the supply side that are feasible is augmentation of power generating capacity through RETs, mainly windfarms and small hydro capacity. In view of the constraints and potentials (discussed subsequently), a realizable target of 3000 MW of windfarms and 1500 MW of small hydel capacity by 2010 is considered feasible if steps are taken today. Based on grid characteristics considerations and keeping strategy evaluation in view, the regional distribution of the generating capacities considered are given in Table 7.1.1.

Table 7.1.1. Power generating capacity additions from RETs (MW).

	April 1990 to March 1995	April 1995 to March 2000	April 2000 to March 2005	April 2005 to March 2010
Northern Region				
- Windfarms	0	0	0	0
- SHP	31	93	155	217
Western Region				
- Windfarms	33 75	56.25	90	112.5
- SHP	15	45	75	105
Southern Region				
- Windfarms	33.75	56.25	90	112.5
- SHP	35	105	175	245
Eastern Region				
- Windfarms	7.5	125	200	250
- SHP	10	30	50	70
North-eastern Region				
- Windfarms	0	0	0	0
- SHP	9	27	45	63
All India				
- Windfarms	75	237.5	380	475
- SHP	100	300	500	700

Additions of conventional power generating capacity in the alternative energy strategy will be the same as in the BAU strategy (see Chapter 2). However, owing to the additions of RET capacity, power shortages will reduce considerably from BAU levels (Table 7.1.2).

Table 7.1.2. Peak demand and energy shortages.

	1994/95	1999/00	2004/05	2009/10
% Peak shortage	15	9	10	10
% Energy shortage	6	~	~	~

~ : < 0.5%

The investment levels are different from the BAU strategy presented in Chapters 2 only to the extent more windfarms and small hydro capacity are installed. Estimates also indicate that average power supply costs reduce with increase in use of renewables due to the benefits obtained in the form of a reduction in energy shortages outweigh the increase in additional RET capacity costs.

The economic costs (which include direct economic costs related to demand and supply side investments and operations, as well as quantifiable environmental costs -- see Chapter 6) of electricity supply, when wind power and small hydro is incorporated into the grid is summarized in Table 7 1.3

Table 7.1.3. Economic Costs of Electricity Supplies in 2009/10 (1990/91 paise/kWh sales)*.

	BAU Strategy	With renewables
NR	286	284
WR	228	224
SR	255	248
ER	279	276
NER	283	280
AI	262	259

* In comparison, the cost of electricity generated through windfarms and small hydropower installations is US cents 20 and 14 per kWh of sales respectively.

Demand side renewable energy options

Alternative energy options on the demand side include the use of solar cookers, biogas plants in the domestic sector

Solar cooker

This is a particularly attractive option in small and medium sized towns and cities (this aspect will be discussed in the second part of this chapter). Taking the present proportion of urban population for these cities (40 per cent) and assuming a penetration ratio of 20 per cent, savings from reduced LPG consumption have been worked out. The same study indicated that solar cookers would be able to replace 20 per cent of LPG for cooking energy demands.

The output of the economic analysis of solar cookers for meeting a part of domestic cooking energy demand is presented in Table 7.1.1, which gives the cost per unit of LPG saved. The annualized incremental investments of this option are worked to be Rs 189 crores. As against specific costs (Table 7.1.4) the economic cost of LPG was worked out to be about Rs 8.6-10.8/kg thus making solar cookers a viable option in some regions of the country.

Table 7.1.4. Cost per unit of LPG saved through the use of solar cookers.

Region	Cost of LPG (Rs./kg)
North	8.46
South	7.38
West	9.00
East	8.28
North-east	11.16
All India	8.28

Biogas plants and improved cookstoves

It has been assumed that the cumulative number of 2 m^3 capacity biogas plants will go up to 5.53 million by the year 2010 under this scenario. Correspondingly, the number of cook-stoves using biogas would also increase. Total investment that are required for this option are approximately Rs. 2093 crores.

The economic analysis of biogas to meet domestic energy demand in rural areas was carried out by taking the annualized cost of the stock of biogas plants and improved cookstoves in the year 2010 and the associated savings in firewood. The results of the analysis presented in Table 7.1.5 below give the annualized cost per unit of firewood saved. These costs which average at Rs 0.29/kg of firewood at the national level are much lower than the economic cost of supply of fuelwood.

Table 7.1.5. Economic analysis of biogas plants.

	Annualized Cost (Rs/Kg of firewood saved)	Annual firewood savings (Mt)
North	0.30	3.27
South	0.27	4.24
West	0.34	5.89
East	0.23	2.44
North-East	0.08	0.62
All India	0.29	16.46

Cost effectiveness of the proposed programme

Table 7.1.6 gives the total economic costs associated with all the renewable energy development plans These include direct economic costs related to demand and supply side investments and operations, as well as environmental costs.

Table 7.1.6. Total economic costs incurred in various development strategies (Rs crores, 1990-91 prices).

	BAU	Strategy II With renewable
Technology	309197	308651
Energy shortage	8725	8354
Environmental	8053	8053
TOTAL	325975	325058

Note: Environmental costs constitute approximately 2.5% of the total costs for each of the strategies. However, this figure is only a partial evaluation, e.g , water quality impacts across the energy systems, air and soil degradation for the enduse stage, etc., have not been costed.

It is therefore clear that the deployment of 3000 MW of wind electric generation and 1500 MW of small hydro is cost effective to the economy and can be economically justified.

Strategy for greater use of renewable technologies

Much remains to be done in so far as achieving the level of deployment of renewable technologies to the extent recommended above. The speed and the impact of the transition to energy systems relying more on renewable sources will depend largely upon the political and financial commitment made and the policies adopted over the next decade or so for this transition.

While costs may no longer be the primary issue in the context of developed countries with environmental concerns such as climate change and long term sustainability becoming paramount, investment requirements cannot be ignored considering the more immediate concerns of developing countries in the context severe financial resource constraints. Opportunity costs of higher investments for a sustainable energy system are likely to be much higher, both qualitatively and in terms of quantity. In this context, the relative reluctance to commit substantial funds for developing and deploying technologies based on renewable sources becomes understandable -- it has probably less to do with lack of foresight or concern for sustainability than with finding means of dealing with more pressing concerns. The renewable energy programme of India must be viewed in this context.

The only strategy that can be defended in the existing financial resource condition in India would be one in which the renewable technologies are commercially viable (assuming that the extensive recommendations of rational pricing of energy in India is implemented). Commercialization of the technologies therefore, is the critical issue.

Before we discuss the strategies for commercialization, the following quote from Kishore (1992), though made in the context of solar thermal commercialization, is extremely pertinent:

> ...it is appropriate to mention that one can not possibly talk of commercialization to a predominantly academic solar R&D community. Of one goes by the number of publications by Indian scientists in the solar thermal area, it would appear that there is a high level of activity going on. But in reality much of the work that is published is theoretical and repetitive in nature, and does not have much bearing to problems faced in the field. *One can not talk about commercialization in thin air without jeopardizing the long term prospects of solar energy utilization.* The first step towards commercialization would be a sincere appraisal of what has been

done, what should be done, and who should do it, as far as industrial R&D in solar thermal is concerned. Such an exercise would bring about various constraints for commercialization clearly. Extensive involvement of experienced entrepreneurs, scientists and users in such an exercise over a prolonged period is a pre-requisite as this alone would ensure that correct priorities are set up in formulating a comprehensive industrial R&D programme for solar thermal energy utilization.

Constraints in wind electric generation in grid connected mode

The major constraints to installing such wind farms are related to the availability of funds, logistics and the world wind turbine turnover capacity. These are discussed as follows:

Funds

The capital cost of windfarms at present is about 28,000/kW, net of customs duty of about 40%. The cost of indigenously produced wind electric generators is expected to be in the range of Rs 32,000/kW. It is estimated that the budgetary requirements to meet the windfarms potential at 2010 is Rs 8500 crores and will add 3000 MW of capacity to the grid.

Logistics

Identification of sites, land availability, modifications in existing grid and actual execution of the projects are the major factors to be considered Earlier studies have shown that the land and wind resource availability are not the major constraints. However, lack of experienced and adequate manpower for preparation of specific project details would be a bottleneck

Annual production capacity

Wind turbines are not domestically produced at present. Also, the world production capacity would have to cater to the increasing demand from Europe, USA and other parts of the world. In Europe itself, a potential of 100,000 MW of windfarms has been identified to be met over the next 40 years or so. The highest turnover from the world wind turbine industry in the last decade has been of about 500 MW. The production capacity is likely to increase with an increase in demand but this increase again is limited done, what should be done, and who should do it, as far as industrial R&D in solar thermal is concerned. Such an exercise would bring about various constraints for commercialization clearly. Extensive involvement of experienced entrepreneurs, scientists and users in such an exercise over a prolonged period is a pre-requisite as this alone would ensure that correct priorities are set up in formulating a comprehensive industrial R&D programme for solar thermal energy utilization.

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In addition, replicating the TNEB in setting up a structure similar to a *wind energy wing* with trained manpower capable of not only installing and maintaining windfarms, but is being able to identify new sites, design grid interfaces, prepare expansion plans/ reports and offer consultancy on wind power development would be beneficial to wind power development. Procedures and facilities for energy banking, energy wheeling, etc., successfully implemented in Tamil Nadu would also benefit both Gujarat and Maharashtra and, in future, Kerala, where a number of good sites are indicated by the Wind Mapping project of the MoNES.

☐ Though there are financial incentives such as the soft loans provided by IREDA (@12.5%) to industries and the provision for 100% depreciation in the first year from the income tax, recent changes in regulation have not been positive. The introduction of a 40% import duty from July 1991, though expected to encourage local production of machines, has adversely affected the wind power development activities.[5] A mature wind power manufacturing industry would have resulted in a short-run impact of this measure. But, as discussed earlier, for the past 5 years, wind turbines were imported without any duty. Coupled with the higher incidence of other taxes on locally available inputs compared to international prices (for example, steel prices in India were 40% higher) provided no incentive for the development of an indigenous industry. With the exception of BHEL (with relatively high cost turbines) and, perhaps NEPC if it decides to exercise the option, the local industry is not equipped to handle the level of demand for wind turbines.

Considering this, the Central Government should seriously reconsider the decision of the import duty. The loss of revenue to the Government due to the temporary withdrawal (say, five years, till a indigenous industry develops) is likely to be marginal (less than 10 crores for the five year period) but the impact to the wind power development efforts will be significant.

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[5] The effect has been severe, according to some, due to the combined effect of the devaluation of the Rupee and the 40% import duty The effect can be gauged from the increase in prices in the installed capacity – from Rs 18,000/kW (in early 1991) to the current cost of Rs 28,000-30,000/kW

- ☐ In order to encourage participation of the private sector in the installation of wind farms, the Government allows a 100% depreciation in the first year of commissioning of the windfarm from the income tax. The condition imposed that the organization/ industry can claim the rebate if the windfarm is commissioned before September of the year. While this measure is a sincere and an effective measure to encourage private sector investment, the time dependent element in this regulation (available to a number of capital investment, including motor vehicles) can often result in a compromise on the windfarm site, machine quality, and grid quality, resulting in a poor windfarm performance.

  Considering the larger social benefits of investment in a environmentally benign electricity generating source, the Government should seriously consider exempting investment in windfarms from the time dependent clause in the Income Tax Act.
- ☐ Pay the wind farm generating facility avoided cost rate for power generation. A legislation along the line of *The Public Utility Regulatory Policies Act of 1978* (PURPA) of USA. A federal (central) law which required utilities to purchase electricity from Qualifying Facilities (QFs)[6] at the utilities' avoided cost.[7] It also exempted QFs from both state and federal regulations as utilities.

Strategies for increased small hydro utilization

The initial batch of small hydro schemes in India were conceived, designed and executed as scaled down versions of large conventional hydro installations As a result of this there are numerous redundancies in the designs for the key features such as the layouts for the civil works, the facilities incorporated into the powerhouse structure, the selection of turbine-generator equipment, and the specification of the electrical switching and protection system. As a result, small hydro is perceived to be both unreliable and a high cost option among those responsible for decision making in the Indian energy sector. This has led to doubts about the possible role of small hydro in the Indian energy system.

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[6] Defined as the power producers that meet certain standards regarding energy source (such as solar, wind, geothermal, biomass, hydro) and/or efficiency of use (such as cogeneration)

[7] In PURPA this is the lowest avoided cost by the utility in producing electricity from new plants It consists of depreciation on the new plant, called the "capital cost" portion, and an "energy cost" portion related to the cost of fuel to operate the plant.

Cost reduction

A recent World Bank survey of the designs of small hydro facilities reveals the possibility of bringing down the unit cost of small hydro plants to one-third of the current costs (which are in the range of Rs 25,000-30,000-/kW) by a combination of design modification and standardization of equipment.

The standardization of the hydro-electrical equipment (water turbine--generator combinations) through establishing technical specification and the consequent improvement in the quality of manufacture and reduction in unit costs by enabling specialized production in batches is another measure which can go a long way in making implementation of small-hydel projects reliable and quicker. This is likely to have another very favorable spin-off. China is a good example. Measures to standardize designs of the equipment for small-hydel stations in China started in 1978. The result of this ongoing and evolving exercise in China is the stipulations for 4 types of turbines, 8 runner series and 32 product varieties. About 85% of all the components now have standardized designs making the production process economical and the components reliable. The standardization process has resulted in products in the capacity range of 500-10,000 kW suitable for water heads of 3-450 m. By 1989, the estimated number of hydro-electrical manufacturers had touched 100 and the annual production capacity exceeded 1000 MW.

In the last few years significant work has been made in the standardization of canal drop shall-hydro equipment in India. Canal falls and irrigation dam sites have been found to vary between 3 to 30 m head[8] and 5 to 50 cumecs discharge. The standardization exercise for grid connected small hydro facilities, based on these heads and discharge has led to design heads of 3, 4.25, 7, 10, 13, 15, 21, and 30 m while the design discharges are 5, 7.5, 12, 2.5, 30, and 50 cumecs. The corresponding generator sizes are 350, 650, 1000, 1250, 1500, 2000, 2500, and 3500 kW respectively (Singh 1992:7).

Sites with head below 3 m are not considered viable

Increasing reliability

The reliability of the small hydro system can be substantially increased through innovative and inter-linked design of small hydro facilities. The measures which can result in further improvement but will require a longer time frame to implement. The design of small-hydel projects on a river basin basis on the principle of cascade development, like the Chinese small-hydel programme, can be a major factor in increasing the potential and the success of the Indian programme. In planning small hydel projects for small river basins, the emphasis should be placed on evolving designs to take advantage of the topography and to arrange the hydropower structure such that the headwork (or the intake) of one station follows closely the tailrace (open canal for tail water) of the other. The upstream regulating reservoirs can then be designed so that the cascade process raises the dependable output of the whole basin system. Such cascade systems, which can be as much as 10-20 MW, can then be integrated to form a local grid. These local grids, in turn, may be connected to a regional grid. Small hydro developed in this fashion can result in rural electrification that is fundamentally different from that of today. electrification will not simply be the extension of the large grid systems, but rather through the development and gradual inter-linking of many small, but growing, local grids. This can have a profound impact on the way in which rural electrification is visualized and implemented.

The idea (see Kumar 1992) of setting up industrial equipment units down the length of one or more canals sequentially or in clusters so that the high engineering, fabrication, managerial, and administrative costs were distributed over a number of sites may also have significant impact. Such an approach along with the concept of promoting manufacture - contractor combines for facilitating turnkey executions, it was hoped, would make possible the installation of high performance equipment for about three meter head within 18 to 24 months at an all inclusive cost of about Rs 25,000 per kW and reducing further with higher heads and capacities.

Promoting private sector participation in small hydel development

Power generation and distribution, though on the concurrent list, is basically a state subject specially for schemes with a capital outlay not exceeding Rs 25 crores which can be taken without clearance from the Central

Government. Following the World Bank condition for involving private developers in small hydro development involving the Bank's money, the state governments have been requested to lay down policy and guidelines to enable private sector generation. Reasonable progress has been made in this direction in some of the states like Karnataka, Tamil Nadu and Gujarat.

In addition, for the non grid-connected systems, it is necessary that entrepreneurs be allowed to operate as licensees of the State Electricity Boards to generate power and distribute and sell it at prices which ensure economic viability of the project.

Fiscal incentives

As indicated earlier, a number of financial incentives allowable to other renewable energy equipment, such as those running on solar, wind, etc., such as permission to depreciate 100% of the capital cost in the first year of purchase under the Income Tax Act, import without any license and generally with duties ranging from 0 to 40%, total exemption from Central Excise and Sales Taxes and now concessional finances from many financial institutions are not available to small hydro users It is believed that the cost reductions possible in this sector if such concessions were allowed in this sector would be at least 25% (Singh 1992) and may have a substantial impact on the small hydro development programme

Initiatives for a effective PV programme

Considering the high cost of the PV technology (exceeding Rs 250,000/kW), severe limitation of funds available with the Government, and the much lower cost technologies like wind power (Rs 30,000/kW) and small hydro (Rs 25,000/kW), the Government should seriously consider the withdrawal from the promotion of solar photovoltaics except for uses (such as education and health care uses in rural areas) with substantial social benefits. The PV sector should be the first of the renewable energy sectors to be left to develop under market conditions. Without doubt, PV is an attractive technology, but hard decisions are required in the larger interest of the renewable energy programme.[9]

With the Eighth Plan outlay of Rs 90 crores, the PV programme is expected to install PV systems with the capacity of a little over 2 8 MW With the same outlay (Rs 90 crores for 1992-97), the wind power programme is to develop 100 MW

With this as the starting point, a more effective and competitive PV industry would evolve if the following steps were taken.

Fiscal incentives

The effect of *import duties* on the price of PV is far greater than the direct cost impact. The interest charges on funds borrowed to cover the payment of duties can only be recovered several months later. The time delay accounts for the time between importing the components and getting paid by the customer.

Import duties are also partially responsible for the lower reliability of a number of PV systems, especially consumer items such as lighting where the buyer (usually the state Nodal agencies who have to finance all the system cost apart form the module) is unwilling to pay a high premium for extra reliability. The high duty on electronics components has forced many manufacturers to build their own controls and inverters instead of importing the systems. Because manufacturers build small quantities of products, unit costs are high, and, as a result, the design specifications may be compromised in order to reduce costs. The resultant loss of reliability and efficiency has a detrimental impact on acceptance of PV products due to low reliability.

While much has been done to improve the duty structure, further rationalization is needed. The assessment should take into account not only the impact on local industries and the Government revenue needs, but also the impact of duties on PV product quality and affordability. Reducing or eliminating duties may allow Indian manufacturers to improve product quality[10] and price and ultimately lead to a much stronger indigenous PV industry. While there will be some short-term dislocations in some companies, it may be better to remedy each on a case-by-case basis, instead of impairing the whole PV sector. This issue is complex and deserves a more thorough and in-depth investigation.

The *exemption from sales taxes* for PV systems has benefits exceeding its pure monetary advantage. The reduction in overhead costs associated with maintaining sales tax records, submission of sales tax receipts, and fulfilling audit requirements is considered an important benefit by suppliers.

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[10] The products for which indigenous production do not exist should be given a much higher priority while considering withdrawal of duty Items such as EVA, Tedlar, and toughened low iron glass fall in this category

Increasing the capacity utilization of the manufacturing infrastructure

The installed capacity of manufacture is 5.75 MWp of modules (of which 1 MWp has export commitment) and with the announced capacity expansions of the Indian manufactures this is likely to go up to 8.5 MWp. The manufacture for 1991/92 was nearly 1.9 MWp. Clearly, this is a sub-optimal utilization of the manufacturing infrastructure and appears to be the most direct way to reduce cost of PV modules.

Post-installation service

The lack of an effective after-sales service network has been a hindrance to the broader acceptance of the products. The consumer acceptability of PV system is influenced not only by the quality of the service supplied, but also by how promptly any technical problems can be corrected. In the past the PV programme[11] as well as the manufacturers have not paid adequate attention to providing effective maintenance support.[12] The problem was aggravated by thinly dispersing PV systems across a large area, thus increasing the cost of accessing these systems.

A possible reason for the suppliers/ manufacturers inadequate attention to post-installation services is likely to be the Government being the main customer. More often than not, the participation of the Government ends with the installation of the system.[13] Post installation maintenance (or arranging for the same) is the responsibility of the community/ institution, which, in the current set-up, has no influence on the choice of supplier or manufacture.

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[11] This is not necessarily true across the board Recognizing the need to provide responsive service, some nodal agencies, such as UPNEDA (UP) and OREDA (Orissa), have set up service organizations to maintain the systems supplied through them UPNEDA has assigned a graduate engineer and two technicians to each district. They are responsible for supporting all renewable energy systems installed with UPNEDA support OREDA has contracted the maintenance services to a private company They service the PV systems supplied through OREDA The village power plants have their own caretaker, paid for by monthly fees collected from the householders The caretaker is trained in supplying basic maintenance and in recording system performance. These need to be replicated by other Nodal agencies

[12] While many suppliers may give a 1-year warranty on their products, they provide the service at the manufacturing or assembly plant One manufacturer in India, however, has set up service centers at the district level in India This manufacturer has also set up a distributor network and has trained technicians assigned to each distributor

Credit and hire purchasing schemes

Commercial sales to private sector companies or to individuals also do not involve credit. Neither is there any consumer financing currently available for purchasing PV systems. In rural areas, banks lend mainly for productive uses. Moreover, as the technology is unknown, banks and financing companies are unlikely to lend for PV systems. However, in the future, leasing and financing companies may be open to lending for PV products if the product becomes more accepted. As the urban market has become more saturated, these companies are now moving into rural communities where the level of discretionary income has been rising.

PV manufacturers have also had difficulty raising capital for plant modernization and expansion. One manufacturer indicated that his loan-to-collateral requirements were 1:4, compared to a more "conventional" industry where the ratio is 3:2. The high cost of funds for capital equipment and for working capital place a high financing burden on PV manufacturers.

Changing the role of MoNES and Nodal Agencies[14]

Since MoNES supplies modules at no cost of the state agency, and the recipient is responsible for the balance of system (BOS), the tendency is to design the system so that the BOS initial cost is minimized. This has sometimes resulted in the use of poor quality and inefficient components, inadequate designs, and poor quality installations (e.g., use of tube lights instead of CFLs, poor quality or undersized batteries, inefficient controllers and inverters, etc.)[15]. A preferred approach would be to design the system so that total life cycle cost of the system is minimized. MoNES has begun efforts in this direction by issuing specifications to guide the design of stand-alone systems. There is, however, no established procedures as yet to determine whether supplied equipment meet the desired specifications. A PV test facility is currently being set up at the MoNES Solar Energy Center with USAID sponsorship.

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[13] Currently, the costs of most PV systems are shared between MoNES and the state agencies MoNES pays for and arranges the procurement of modules directly from the PV manufacturer The state agency secures a contribution from the beneficiary, which together with the state contribution pays for the balance of systems and installation The beneficiary contribution varies from state to state It is usually only 10 to 25 percent of the total cost made in a lump sum In the case of village power systems, however, each householder pays Rs 10 per month These funds pay only for the maintenance technician

In the current set-up, therefore, the MoNES is responsible for providing the Modules to the State Nodal agency, which, in turn, is responsible for obtaining the BOS and installation The involvement of the Government, in most cases, ends with the installation

[14] This is only valid for the limited involvement of the MoNES in the sectors with high social returns for investment (health care and education)

Strategies for increasing solar energy utilization

Strategies for increasing the penetration of hot water systems

- ☐ *Identifying the correct market segments*: Since solar water heating systems appear to be cost effective only when hot water is required round the year, hotels and urban households satisfying this criterion (and using electricity for water heating) are the best target segment for domestic hot water systems
- ☐ *Cost reduction*: It is apparent that attempts to demonstrate the efficacy of systems with a lower initial cost should be strongly encouraged. This could be through innovation in manufacturing and finding lower cost substitute material Focus of technology development must be on systems with cheaper/ alternative materials, such as shallow solar pond based systems, salinity gradient solar ponds, etc as the initial cost of these systems is much lower.
- ☐ *Improving performance*. By corollary of cost reduction through innovation, attempts to impose 'standards' on the system could thwart initiative from entrepreneurs and research institutions in developing innovative designs or improvements. The system performance, both short term and long term, should be the main criterion for promotion.

  Cost reductions may also be possible by substantial improvement performance at higher cost. The use of low iron content glass and selective coating are possible options in this category.

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[15] CFLs are currently imported and their distribution across India at present is poor Some companies are planning to manufacture CFLs in India

- A major problem experienced by the users of solar systems increasingly is related to scale formation. The water supplied in most Indian locations is sufficiently hard to cause scale formation, which, due to the peculiar geometry of the flat plate collector, is difficult to remove. Hence, any research aimed at rectifying the affected systems or at controlling/ eliminating scale formation, should be encouraged.
- A serious limitation of the currently available water-in-tube flat plate collectors is that they can not be used in hilly areas such as H.P., North-east etc. which frequently experience sub-zero temperatures. From an ecological point of view, use of solar water heaters in the hilly areas is highly desirable and hence development of heat-pipe based collectors and collectors with phase changing fluids could be given a top priority for R&D. There had been attempts in the past in this direction but none leading to commercial manufacture in India.
- Efforts are required to develop software for design/performance predictions of solar systems. Indian solar scientists have not made serious attempts to develop suitable software for application to real systems in the country.[16] Even the radiation data is not available in the form of TMY (typical meteorological year) for different locations in the country. To establish the commercial viability of a system, it is essential to estimate the monetary savings with a reasonable accuracy, and this is possible only with the help of proper software. A system which performs much below the expectations of the user can never be commercialized

Strategies for increased solar cooker penetration

For similar reasons, more effective marketing and higher penetration may result, at least in the initial period, if solar cooking devices are marketed through LPG dealers.

- *Product development*: Efforts should be directed at developing user-friendly, marketable appliances. For example, a light-weight, single pot solar rice cooker with electrical back up might be eminently marketable. But this kind of developmental activity is easier said than done. Firstly, such a developmental effort is best done by the entrepreneur or manufacturer, but these at present operate at a very small level and have no capacity for carrying out any in-house R&D.

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[16] A direct result of this is that we have only thumb-rules in selecting the size of the system for a given application Thus, we employ the ridiculous assumption that 1 m2 of collector will yield 50 liters of hot water at 60°C (or above) any time of the year anywhere in India This would lead to undersizing of the system in the northern climates and oversizing in the warmer, southern climate There are no reports, for example, which give the year-round performance of a domestic, thermosyphon system neither under the actual conditions of use, nor under simulated conditions Hence, there is an urgent need to develop suitable software for design and performance predictions Imported software such as TRNSYS may not be applicable for Indian conditions At least, there could be some attempts to validate the use of available software to Indian systems

There had been some efforts to develop a more complete solar cooker using parabolic dish type collectors. But these efforts had been sub-optimal and had not received any official encouragement. In contrast, China had developed several indigenous designs of concentrating type solar cookers, which seem to have been accepted well. Such cookers can be effective for community applications and research aimed at product development in this area should be encouraged.

☐ *Identifying the market*: Since solar cooker is not a complete cooking system and supplements whatever cooking system is being used by saving fuel, the relevant target market are households using commercial fuels for cooking As discussed, convenience (which includes availability of the fuel) plays a decisive role in determining the cooking technology choice. LPG is, therefore, the most preferred fuel choice The widespread shortage of this fuel, much more severe in smaller towns, would indicate that the most attractive market segment would be households using commercial fuels willing to pay a premium of about a thousand Rupees to decrease the inconvenience of the uncertainty of the availability of the preferred fuel Much larger number of such households are likely to be found in towns and cities (as opposed to metropolitan centres)

Strategies for an effective biogas programme

Since its inception, biogas has established itself as a technology with great potential which could exercise major influence on the energy scene in rural areas. Yet the experience so far shows that the field level performance has not matched the expectations because of various factors, (some have been discussed earlier). Hence, there is a need to take serious steps that could translate the high potential into high performance. Listed below are some measures for biogas to have a perceptible impact.

Review of the implementing strategy

Considering the population and area and the constraint on financial resources available with the government, it is clear that government-sponsored interventions in the rural energy sector can, at best, play only a catalytic role. Logically, therefore, all rural energy programmes should be directed where the chances of success are the highest rather than to spread out too thin, particularly in the context of severe financial resource constraints in India. Regions requiring interventions would correspond to areas where energy (or the lack of it) is the felt need of the people. This approach also reduces the manpower required for post-installation service of technologies and is likely to facilitate the creation of a more effective post-installation service. Looked at from another perspective, the existing implementation process should be altered such that the installed technologies are not too dispersed for effective post-installation attention -- it is relatively easy to plan and provide for manpower, spares, etc., for post-installation maintenance in a geographical cluster of (say) 20 villages with 400 biogas plants than to provide a similar facility for 400 biogas plants in 400 villages. Considering the fact that this has been a common and, perhaps, the most serious problem associated with the way national intervention programmes like the NPBD and NPIC have been implemented, this is likely to translate into substantial benefit for the diffusion of renewable technologies.

A need-based approach should be adopted rather than a target-oriented one. This can be achieved only through integrating the plan for biogas development into an overall energy plan for a particular region or ecosystem instead of deciding targets in isolation Such energy plans could then be integrated at a higher level for policy making, budget allocation, etc

Priority should be given to areas (disagregated to the district level for the obvious reason of ease in planning and implementing programmes form this level) where the lack of energy is perceptible.

Designing effective technology delivery systems

Multi-agency approach adopted in the NPBD has provided rich experience of implementing rural energy interventions on a large scale. The biogas programme has been implemented, with varying degrees of success, by a wide range of agencies operating at differing geographical scales. These range from Khadi and Village Industries Commission (implementing programme at the national level), Gujarat Agro Industries Corporation (implementing at the state level), to the Block Development Officer (at the Block level) in the Government to Action for Food Production (at the national level), Gram Vikas (at the state level) to local level NGOs.

All agree that the delivery system for the biogas technology can be improved. The starting point of such an exercise would be to examine the effectiveness and the efficiency with which different agencies have executed the implementation process and to, thereafter, design an effective delivery to the extent that the diversity of rural India permits.

Rich beneficiaries, subsidy, and commercialization

Eligibility for installation of household biogas plant requires the household to possess the requisite number of cattle. Common grazing practices result in the requirement of at least 3 heads of adult cattle for the smallest (1 m^3) biogas plant and the possession of the requisite cattle heads implies a certain degree of affluence. This, and the scattered results of the ownership profile for the technology,[17] would indicate that the NPBD may be subsidizing the rural affluent, who can afford the technology without the government subsidy. It may, therefore, be worthwhile to commission a study to determine the profile of owners of the technology. Such a study may guide the policy on subsidies on the technology and help in a quicker commercialization of the technology without government support.

Developing low cost designs

In order to make the biogas available to poor who actually need it, low-cost designs must be developed. 'Deenbandhu' is a positive step in this direction and so is the 1 m^3 plant though it cannot meet all the fuel needs of an average family

Alternate feedstocks

The efforts in research and development should be expedited to produce alternative feedstocks, building materials, etc. Special thrust should be given to microbiology of biogas to develop bacteria that could work at low temperatures, with low water consumption, so that biogas could be used all over the country uniformly.

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[17] For instance, a study in Madhya Pradesh showed that most plant owners were affluent professionals such as doctors and lawyers Another study reports only 2 to 5% of the biogas plant owners in Karnataka and Maharashtra, 10% in Marathwada and 20% in Gujarat belonged to scheduled caste and scheduled tribe communities In Madhya Pradesh, none of the 775 plants surveyed belonged to a family from these categories

Commissioning of plants

Initial charging of the biogas plant, which requires 1500 kg/m^3 of dung, has proven to be a bottleneck in commissioning biogas plants. It is necessary to add the cost of dung acquisition in the total cost of the plant and ability to arrange for dung, a precondition to install the plant.

Evaluation studies of CBPs

There is a need to conduct large-scale evaluation studies on CBPs to learn from the experiences, so that better planning could go into their dissemination in future.

Strategies for effective implementation of NPIC

Review of the implementing strategy

Rationale for the review of the implementation strategy is similar to that outlined for the biogas technology. Government-sponsored interventions in the rural energy sector can, at best, play only a catalytic role. The NPIC, therefore, should also be directed where the chances of success are the highest rather than to spread out too thin. In the case of cookstoves, however, an additional step is required and an effective programme design would require.

1 identification of regions requiring interventions.[18] These would correspond to areas where energy (or the lack of it) is the felt need of the people, and

2 a study of the cooking energy system[19] for working out the appropriate cookstove design suitable to the cooking practices of people.

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[18] This has additional advantages Studies indicate that improved cookstoves tend to be used properly and perform better in areas facing fuel scarcity (see Joshi et al 1990)

[19] Cooking energy system, as used here, includes the fuel and vessels used for cooking in addition to the cookstove and the functions that the cookstove performs

CHAPTER 8

Programme and projects

8.1 Introduction

The programmes and projects proposed here address the alternative energ strategies discussed in Chapters 6 and 7. A few proposals also relate to the concerns that are not part of the alternative strategies but refer to the major ongoing activities. Broadly, these represent either studies needed to develop larger programmes, strengthening on-going programmes or new programmes. Broadly, these represent either studies needed to develop larger programmes, strengthening on-going programmes or new programmes. A prerequisite for implementation of the proposed strategies is rational energy prices Hence, the following study is proposed.

Objective

An evaluation of the policy instruments available with the government to bring about improvements in energy efficiency and to move towards the national objectives of sustainable development.

Scope

This would be a futuristic study to be framed in the framework of sustainable development for the country's large population. It would involve an examination of "lifestyles and resource needs" in the context of the large population. Such an exercise would lead to development of a long term energy policy and will provide a framework for evaluating the policy instruments Important among these would be the impacts of current energy pricing on energy efficiency, energy demand and energy mix Such a study could propose a rational pricing of energy supply and examine the implications such a policy would have on different sectors of the economy. The constraints in the implementation of these measures need to be addressed to see the efficacy of available policy instruments.

Proposals for alternative strategy I

Coal

C1. Coal gasification

Increased opencast mining has been one of the contributors to the decrease in the quality of coal. Coal supplied to power plants is expected to contain a percent of ash greater than 40 in the coming years. Given the predominance of coal in India's energy mix, the environmental impacts of its combustion are another important aspect to consider when assessing present technologies for transformation. It is extremely important for India to develop technologies for the effective utilization of indigenous coal reserves for the production of a fuel which can be used in the industrial and domestic sectors as well as for pollution free electricity generation. In this context, it is important to continuously upgrade coal utilization technologies in order to minimize energy costs and environmental damage

One such technology is the integrated gasification combined cycle. At this point it would be relevant to review the status of this technology in India.

The commercialization of IGCC power generation would depend on the rate of transfer or development of technology in India and its diffusion. Demonstration units can be set up in one of the existing pulverized coal power plants where upstream facilities for coal, downstream facilities for hot gas and disposal system for slag, stack gas and effluents already exists

C2. Coal beneficiation

It is estimated that the demand of coal for power stations beyond 1000 km from the source of supply would be about 65 mt in 1990 - 2000. In response the Government of India has, in principle, decided to supply washed coal (non-coking) to power plants located over 1000 km from the supply source. Two washeries, with a total capacity of 14 mt/annum, have been sanctioned and are currently under construction. However, the process of washing cannot be generalized to all coalfields, since in some coalfields small sized coal has a lower ash content than the coarse size while in others the converse holds true. Hence, the investments can only serve as an order of magnitude estimates of finances required in the coal sector.

In addition to the inherently high ash content of Indian coals, the deposits are generally associated with dirt bands which are usually carbonaceous and therefore combustible. Thus, unless the process of beneficiation is capable of giving a sharp cut of separation, the chance of high ash material going with coal and coal going with rejects is substantial. If the entire size range is washed (from fine coal to coarse coal), the process will be exceedingly costly and a considerable amount of moisture (which ultimately gets transported to the consumer) is added to the coal. Conversely, if washing is restricted to coarse coal, the degree of beneficiation is small.

For these reasons, a major improvement in coal quality with simple beneficiation does not seem possible as yet. It was in this context that the Expert Group on Integrated Gasification and Combined Cycle Power Generation recommended that "an intensive, urgent, time bound R & D programme be carried out in India, by CSIR and CMPDI, on washing of coal to reduce the ash content from 40 per cent to about 25 per cent and to establish the recovery and economics of washing". This washed coal was to be then tested for gasification using different technologies Recently, a West German company has developed a simple jig (ROM Jig) for washing coarse fractions of the run-off-mine coal. A full size plant on this technology is under construction at one of the mines in Singrauli Coalfield.

It is hence proposed that future investments should concentrate, through the establishment of pilot plant facilities at select locations, on:

a) Characterization of the cleanability of Indian coals from different coalfields;

b) Assessing the different technologies available and their costs;

c) Developing improved coal washing technology suitable for Indian coals.

Power sector

P1. Reduction of T&D losses

The transmission, distribution losses in our country are of the order of 22%. Reduction in T&D losses would then indirectly help the environment. In this connection both technical and administrative measures would be required to be taken.

Objective: To study the effect of T&D losses before and after the implementation of various technical and administrative measures.

Scope: Areas could be selected in different regions in the country to undertake demonstration projects to reduce T&D. The results of the study could be usefully employed for reducing T&D losses in the other districts/zones.

P2. Saving in demand for electricity by having two time zones in the country

The question of having two time zones in the country with a view to effect savings in demand for electricity has been under discussion for sometime past and preliminary studies were also made in this respect but no definite conclusion could be drawn regarding having two time zones in the country due to limited data.

Objective and scope: It is proposed to carry out a study of the load pattern in the Eastern and Western regions of the country which would be largely affected by having two time zones, in respect of various categories of consumers namely domestic, commercial, industrial, agricultural etc. The possible savings that could be had by having two time zones would be studied and appropriate recommendation framed.

P3. Demonstration projects on energy efficient lighting

A task force on energy efficient lighting was constituted with Joint Secretary (EMA) as Chairman and Energy Management Centre (EMC) as Member Secretary decided that a number of demonstration projects should be launched in the areas relating to commercial, domestic, five star hotels and street lighting. The demonstration projects would include white fluorescents, compact fluorescents, triband lamps and accessories such as new design of ballasts, power factor correction capacitors etc. This proposal relates to demonstration project for Commercial Buildings, Five Star Hotels, Residential Sector and Street Lighting.

Objective: The main objective of this project is to demonstrate energy efficient lighting by introducing white fluorescent lamps, compact fluorescent lamps, triband lamps and accessories such as new design of ballasts, p.f. correction capacitors etc.

Scope: The demonstration project will

1 study performance of energy efficient light sources and accessories under actual supply conditions,

2 obtain data on failure rates of new light sources and accessories and

3 study consumer responses and preferences to the new light sources and accessories.

This project is also expected to identify any other problem that may be a constraint in the introduction and use of new energy efficient lighting systems.

The locations chosen for commercial buildings, five star hotels and residential sector will be chosen such that the performance can be studied under different supply conditions; firstly steady and regular supply and secondly under erratic supply conditions with sudden spikes and dips in the supply. Keeping the above conditions in mind, it would be preferable to carry out the demonstration projects in Delhi and Calcutta.

The cost of replacing the existing bulbs with more efficient ones could be obtained over a period of time by the utility based on the savings obtained

P4. Performance of pollution control measures in TPS

The environmental control measures have been installed in most power plants However, information on their operation and performance is not gathered Environmental audits should be conducted to collect this information and also make it available for environmental planning.

P5. Assessment of ongoing R&M, uprating and life extension schemes

The schemes initiated to improve the performance of power plants require monitoring to ensure efficiency in their implementation. A demonstration project could be set up for a few plants to develop models for implementation of such projects.

Transport sector

T1. Strengthen the public transport system

A comparative analysis of bus vis-a-vis other modes in meeting 1 million pkm of travel demand reveals.

- ☐ a car consumes 6 times more energy than that of a bus, whereas, two-wheeler consumes 2 times and three-wheeler consumes 4 times.
- ☐ a car occupies 44 times more road space in comparison to a bus. The corresponding figures for two-wheelers and three-wheelers are 73 and 21 respectively.
- ☐ the cost of operation of two-wheeler is 22 times, three-wheeler 27 times and car 30 times when compared to bus.
- ☐ a similar advantage of bus is observed when emission of CO, HC and NO_x levels are considered. A car emits 90 times more CO, taxi (113 times), three-wheeler (60 times) and two-wheeler (49 times) when compared with a bus. Similarly, with regard to HC emission, the corresponding figures are 43, 55, 121, 100 times more respectively. NO_x emission from car and taxi is 3 and 4 times respectively than that of a bus.

This suggests, the desirable cost-effective solution to move people with less vehicles using less energy and spewing out less pollution could be achieved by increasing the share of public buses public transport

Like for instance, an increase in bus share from 57 per cent to 80 per cent in 83 cities[1], would lead to a saving of 1.1 million tonnes of oil [TERI, 1989] by the turn of the century. The other advantage is that ensue are a 54 per cent reduction in total vehicles on the road, a 36 per cent reduction in air pollution and a 33 per cent reduction in transport costs [TERI, 1989]. This also suggests an additional 25,000 buses by 2000 A.D. for the 83 cities. At today's cost this would mean an additional investment of Rs.1,000 crores. If we add 30 per cent for investments in infrastructure we need Rs.108 crores per year till the turn of the century to provide the requisite additions to buses.

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[1] As per the projection of the Study Group on Alternative Systems of Urban Transport set up by the Government of India, there would be 83 cities in India with each over 0.25 million population size during 2000 A.D.

One disadvantage is that about half a million tonne of diesel fuel will be required in addition implying additional imports. This can be got over if two further measures are implemented:

- ☐ increasing the traffic carried by electrical suburban rail systems in metropolitan cities by 50 per cent more than that projected by the Railways (i.e., 26 BPKM more) giving a saving of 160 thousand tonnes of diesel.
- ☐ improving fuel efficiency of buses from 3.5 kmpl to 4.5 kmpl leading to a saving of 400 thousand tonnes of diesel. This could be done partly by technological improvements in bus design and partly by traffic management measures leading to less congestion and faster flow of bus traffic.

T2. Shift from road to rail in freight movement

The question arises why the road freight traffic is growing so phenomenally even though there are many impediments to its growth. The reason could be that the road transport is operated mainly by individual operators thereby providing a competition which is lacking in the railways. The keen competition aspires the road transport operators to provide personalized and/or customer oriented service. Other characteristics of road transport that are helping it to take away the rail traffic are:

- ☐ Door-to-door service reduces handling and hence probability of damage to goods, and saves on handling and cartage to and from terminals
- ☐ Faster, reliable and regular service reduces in transit inventory and customer's inventory costs by adhering to regular schedule.
- ☐ Movement of smaller consignments by road allows catering to dispersed demand of a larger group of customers.

With the limited and dwindling resources of petroleum products and critical position of balance of payments, it is in the interest of the country to encourage long distance freight movement by the railways, keeping in view the requirements of the shippers/customers. This could be achieved through a domestic container service, matching the shippers requirements, with container loads of say up to 10 tonnes. The main benefits of a proper domestic container service would be faster transit, lower operational cost, minimisation of time loss in switching from one mode of transport to another, protection against climatic hazards, minimisation of packing cost and damage during transit, reduction in handling and overall improvement in the quality of service.

T3. Implementation of metro rail

In major metropolitan cities, a case is often made for constructing metro system along high density routes as a long term cost effective solution. The present traffic situation in Bombay, Madras and Delhi, do justify the underground rail corridors, but the heavy investments required for constructing such corridors become a limiting constraint. Funding from the external sources has to be called up on. The Government is not able to implement metro rail system in Delhi to start with and other cities subsequently, for want of institutional infrastructure and adequate finances for the massive investment required. Yet, the net benefits to society from an appropriate metro system would be substantial and exceed those from other alternatives. A concept that needs to be explored is that of the build-operate-transfer (BOT) option This option would not only ensure quick and efficient implementation of the project but also bring into existence management and operational expertise which is essential for maintaining the system, once established, at high levels of efficiency. The Government of India should seriously consider pursuing this possibility.

T4. Conversion of two-stroke to four-stroke engines in 2-wheeler and 3-wheeler vehicles

Most of the two and three-wheeler vehicles currently being manufactured in India are powered by petrol-fired, two- stroke engines of poor thermal efficiency. A study by the Indian Institute of Petroleum highlighted that more than 50 per cent of the potential energy in the fuel is wasted in the exhaust gases from the engines, which contain combustible gases in substantial quantities.

Four-stroke engines are more energy efficient than two- stroke engines. Also, unlike a two-stroke engine, they do not consume lubricant oil. However, there are some advantages associated with the two-stroke engine and these have inhibited a change over to the four-stroke engine. In a two-stroke engine every second stroke is a power stroke instead of only one in four in a four-stroke engine. Therefore, a two-stroke engine of given weight and size gives more power than a four-stroke engine. Moreover, as the two- stroke engine does not require a complicated valve gear system, it is more compact and less expensive From considerations of both energy conservation and reduction of pollution, it is necessary for the Indian manufacturers to switch over to the manufacture of four- stroke engines. This would require large capital investments as the entire manufacturing process would require revamping Since the automobile industry is largely an assembly line operation, a change in the system design would imply that a change in inputs from the ancilliary industries, and hence a change in their production systems, would be required. All this adds to the cost of the venture and, hence, to the reluctance of manufacturers of two-stroke engines to switch over to producing four-stroke models. As of today, only one out of nine major manufacturers has implemented this change.

To induce other manufacturers to make this change over government regulations would be required. These might, however prove difficult to implement, unless phased over a long period The Government would have to ensure that the production of four-stroke engines are made exceedingly attractive by granting incentives to producers and, possibly, consumers. Till such time that this shift occurs, a parallel effort could be directed towards improving the efficiency of two-stroke engines. This could be done by improving transmission systems, use of aluminium cylinder blocks and lighter materials contributing to weight reduction, use of higher rpm engines giving higher output per cc, electronic ignition, adequate cooling, and efficient filtration of intake air and through more efficient manufacturing techniques. A committee with representation from the automobile industry and the Government could be set up to thoroughly investigate the costs involved, time frame required for the change and the role the Government would be expected to play in the future.

T5. Use of CNG in transport sector

Objective: To promote CNG in metropolitan transport system
In India, the present cost calculations for assigning priorities for the use of natural gas do not consider the very high costs that entail the transport of crude and diesel to the Northern region, which is at least 1000 kms away from the oilfields and ports on the Eastern or Western coasts. In addition, there is an absence of dynamic factors in calculations as there are no linkages with international crude oil prices. Refinery margins have also been made while assigning priorities for the use of natural gas. The calculations consider the economic costs of domestic crude oil only. If corrected for transport costs and border prices, natural gas substitution for petroleum products in the transport sector could be well ahead of fertilizers, the power sector and industry.(14) This implies that the opportunity costs of natural gas for uses in different sectors would have to be recalculated and a new set of priorities defined.

Recently the Gas Authority of India Ltd (GAIL) has commenced field trials to develop the use of Compressed Natural Gas (CNG) in the transport sector. A tie-up with the Delhi Transport Corporation (DTC) was negotiated to convert 10 buses to a diesel - CNG mix. The three major activities of the demonstration project were (i) construction of refueling facilities (ii) conversion of diesel powered vehicles into diesel - CNG mix and (iii) the practical testing of these vehicles. This was undertaken in a bid to build confidence in the transporters and other authorities with regard to CNG-powered vehicles.

Further, activities covered under the scheme would include (i) conversion kits (ii) CNG filling facilities and (iii) trials for trouble- free run of 15000 kms for each bus. Since natural gas retrofits require heavy front-end investments, commercialization should only occur in those areas where gas supplies are easily available. The commercialization would require infrastructure provision in terms of a local distribution network and, therefore, its development could be in line with the city distribution network. This tie-up with the local distribution network would help reduce pipeline investments. The economic cost of replacement of diesel by CNG at present prices without distribution/compression costs is higher.

In order to increase the penetration and thus the market share of these vehicles active participation from gas utilities would be essential. In addition, the existing low levels of awareness about the concept and the expected fuel cost savings would have to be done away with. Inadequate post conversion follow-up and support in terms of proper servicing of vehicle and refueling stations would also hamper penetration.

Hence, what is required to popularize the use of natural gas vehicles is

1 national standards on equipment used in natural gas vehicles (NGV)
2 dissemination of data on performance of NGV especially in comparison with petrol-driven ones.
3 installation costs of refueling stations should be optimized.
4 a 'special' rate i.e. subsidy should be applicable.
5 awareness through seminars etc increased to the purchase and use of NGVs.
6 certain facts with regard to the information dissemination on the range and driveability of CNG vehicles.

Industrial sector

II Promotion of energy conservation in industries

Despite best intentions and some good policies, the effort has failed to make a headway; some of the causal factors being an inadequate information dissemination system, the sporadic and ad hoc nature of the activities and the present uncoordinated approach. If the target set in the eighth plan of energy savings of about 5000 MW of electricity and 6 Mt of petroleum is to be achieved, concrete steps are required urgently.

Energy conservation can primarily be achieved through the adoption of alternate, less energy-intensive technologies and/or substitution/supplementation of conventional sources by renewable ones. As a counter view, it has often been suggested that the uncertainties in supply trigger off inefficiencies within the manufacturing sector eg. unsure supplies and frequent breakdowns promote an increased reliance on diesel gensets to generate the power required. Thus, sorting out the supply situation could curtail excess consumption per unit output. Therefore, investments for conservation would be determined on the basis of whether supply or demand side conservation/efficiency improvements are considered. In the subsequent section, demand side investments are considered. The Inter-Ministerial Working Group on Energy Conservation as far back as 1983 submitted that energy conservation be funded as a separate programme and a revolving fund with a capital of Rs.100 crore every year, over a span of 10 years be set up through the levy of a conservation cess on the industrial consumption of petroleum products, electricity, and coal. The Working Group was also of the opinion that manufacturers of energy efficient equipment should also be given incentives similar to those granted to the users of the equipment. More recently, the National Productivity Council (NPC), on the basis of energy audit reports of 200 industries, has estimated that the annual energy consumption (in 1983) was of the order of Rs.7700 crores of which over 25 per cent or Rs.1900 crores could be saved through a one-time investment of Rs.3600 crores. The Kapoor Committee (The Inter Ministerial Working Group on the Utilization and Conservation of Energy, constituted in 1981) indicated that an investment of Rs.5140 crores in conservation measures could avoid an investment of Rs.7980 crores for the creation of additional capacity in the energy sector and effect annual savings (of energy) valued at Rs.3100 crores. This implies that the investment can be recouped in 2 years with associated returns in the region of 60% per annum, besides obviating the need to tie up large quantities of capital in capacity creation. Currently, the untapped conservation potential within the sector has been estimated in the Eighth Plan to be in the range of 25-30%. In order to achieve this, norms and targets for the energy intensive industries need to be fixed, since policy implementation would occur at the plant level only if cost-effective to the actual user.

Study 1

Given that six industries (iron and steel, cement, pulp and paper, fertilizer, aluminium, petrochemicals - including chemicals and refineries) account for about 60 per cent of the industrial energy consumption in the country, there is sufficient reason to emphasize industry-wise/plant-wise energy conservation technology plans. For this industry-wise efficiency norms would have to be established. In the preparation of energy efficiency norms and targets for the individual industries, current domestic efficiencies should be compared with those of the worlds best technologies currently available to estimate the potential for substitution. The variables which could be considered are current capacities, planned expansions, capacity utilization, location, technology, raw materials used, their substitutability, etc. Further, the compatibility of the current raw materials available in the country to the current (and optimal) output mix could also be studied. Management issues should simultaneously be investigated. Keeping in mind both the feasibility (technical and managerial) of the change as well as the economic consequences of the policy measure, policy instruments required to affect the change will be determined Failure of previous policy measures should also be studied.

Study 2

For energy conservation to be undertaken spontaneously by firms it is imperative that the investments be made financially attractive, either by correcting the energy pricing structure (so as to reflect the true scarcity of the energy source/economic price of the source) or by the introduction of incentives for investing/disincentives for non-compliance. However, given that the prevailing (energy) rates in the industrial sector are close to economic prices, the price increase might not bring about the expected benefits of a reduction in energy consumption. Further, the adoption of energy conservation measures are often restricted by inefficient/outdated machinery. It is in the case of unplanned obsolescence, primarily brought on due to the import/purchase of outdated technologies, that an inability to undertake a retrofit/replacement might arise In order to prevent this import (of outdated, inefficient technologies), it might be worthwhile considering the setting up of technical advisory and screening groups for individual industries. The advisory and screening groups could provide information (including costs) on the worlds best technologies available, for the given raw material mix, the import procedures, and could also screen all applications for import.

Some of the incentives to the industrial sector for investments in energy conservation could be the financing of commercially viable energy efficient and/or pollution control technologies at concessional rates and made attractive through fiscal and pricing incentives and selective legislation. This would require a detailed study of the existing legislation and incentives; reasons for their non-acceptance by the industry or slow penetration; requirements of the industry itself; information dissemination as regards the incentives; database creation on energy efficient technologies, their economics and domestic availability. It has often been commented that the most potent incentive to curtail consumption would be to raise energy prices to the level where investments would be attractive/worthwhile; impose penal rates on those who exceed the norms and fiscal incentives to those who improve on the norms.

Industrial sector

While the need for energy conservation has never been questioned, its true importance was realised only subsequent to oil crises. In India, planners down the decades have emphasised and re-emphasised this point, but with little or no avail. Energy conservation has really remained outside the main domain of policy planning and implementation.

In more recent years, there have been efforts on the part of the government to promote energy efficiency/conservation in the industrial sector, given that this sector accounts for about 50 per cent of the commercial energy consumed in the country. However, despite best intentions and some good policies, the effort has failed to make a headway; some of the causal factors being an inadequate information dissemination system, the sporadic and ad hoc nature of the activities and the present uncoordinated approach If the target set in the eighth plan of energy savings of about 5000 MW of electricity and 6 Mt of petroleum is to be achieved, concrete steps are required urgently.

There exists considerable untapped conservation potential in the range of 25-30% within the sector, but in order to achieve this, norms and targets for the energy intensive industries need to be fixed, since policy implementation would occur at the plant level only if cost-effective to the actual user. In the preparation of energy efficiency norms and targets for the different industries current domestic efficiencies can be compared with those of the worlds best technologies currently available and the potential for substitution estimated. The variables considered could be current capacities, planned expansions, capacity utilization, location, technology, raw materials used, their substitutability, etc. Further, the compatibility of the current raw materials available in the country to the current output mix could also be studied. Associated management issues in the industry can simultaneously be investigated. Keeping in mind both the feasibility (technical and managerial) of the change as well as the economic consequences of the policy measure, policy instruments required to affect the change will be determined. Failure of previous policy measures could also be studied.

Further, what is imperative is that commercially viable energy efficient technologies be financed at concessional rates and made attractive through fiscal and pricing incentives and selective legislation. This would require a detailed study of the existing legislation and incentives; reasons for their non-acceptance by the industry or slow penetration; requirements of the industry itself; information dissemination as regards the incentives; database creation on energy efficient technologies, their economics and domestic availability.

Agricultural sector

A1 Improvements in pumpset efficiencies

Objectives and scope: Experiences till date indicate that more detailed studies need to be conducted for assessing accurately the possible measures that can be employed to enhance the performance of irrigation pumpsets. It is very important to monitor the actual effect of the retrofits to the utility through ***feeder level monitoring*** of the energy consumption The retrofit jobs should not be restricted merely to replacement of pipelines or pumps, but should take into account a host of other factors many of which are site specific. In this context, it may be worthwhile to develop a mobile team of trained personnel, equipped with requisite instrumentation and tools to undertake site visits, decide on the exact nature of retrofits and execute the job in a professional manner. Suitable legislation could be formulated to make standard equipment and power capacitors compulsory in rural pumpset connections. Suitable incentives need to be worked out to encourage quality control and adherence to standards by the manufacturers (small-scale units) of irrigation pumpsets. There is also considerable scope for improvement in the design of centrifugal pumps for agricultural applications.

Project Ideas for renewable development

chnological advances and innovation in utilization of renewables are
eded, but the revolution required is one of attitudes to dispel the wide-
read feeling among those associated with energy planning process and
ergy supply organizations that these technologies and their role is grossly
errated. One way of achieving this is to set-up substantial generating
pacity based on renewables in the Eighth Plan period itself. Two program-
es have the capability to achieve this -- wind farm and small hydro power
neration.

The wind mapping program of the DNES has identified several
otentially windy regions indicating a fairly large potential for wind energy
tilization. The exact potential for windfarms in India, however, is yet to be
roperly assessed and the estimates vary between 20,000 - 47,000 MW.
Vind energy power generation in the regions with windspeeds of 5 m/s or
reater at the hub height of the turbines is considered to be economically
iable in the Indian context. Based on the expansion plans and growth in
the capacity of the various regional grids, the exploitable potential of
windfarms total to over 29,000 MW by the end of the 9th plan (1997) itself.

Based on the potential and the existing infrastructure in India, it is possible to install wind farms of additional capacity of 500 MW in the next 5 years. The only constraint would be the availability of financial resources (approximately Rs 1500 crores for 500 MW). Similarly, additional capacity (in addition to those planned for the Eighth Plan) 200 MW of small hydro requiring an investment of approximately Rs 600 crores would go a long way dispelling doubts, indicating that renewable energy RETs can no longer no relegated to the backwaters of industrial and policy process, and that their impact can be swift and substantial

Other project ideas which could further help the deployment programmes of renewables are summarized below.

R1. Policy measures and incentives to facilitate wind power generation

Rationale: The private sector is being encouraged to participate in wind power development through a number of fiscal and financial incentives. Measures such as 100% depreciation in the first year deductible from the income tax, soft loans provided by IREDA (@12.5% interest), wheeling of energy generated (at 2% of energy generated at the wheeling charges) to the industry's plants have made wind power generation attractive. For instance, the installed capacity of wind generators for captive power generation is reported at 4.75 MW in 11 companies in Tamil Nadu.

Considering the success of some of the measures, there is a urgent need to review the incentives in place and, if felt desirable, recommend additional measures in the context of the pricing policy in the energy sector as a whole. A more comprehensive and integrated set of measures and/ or legislation, perhaps along the line of *The Public Utility Regulatory Policies Act of 1978* (PURPA) is likely to be extremely useful for wind power development in particular and the renewable energy programme in general.

Objectives.

1 identify, collate, and examine the impact of the existing financial incentives,

2 propose and examine the impact of additional incentives, and

3 prioritize the recommended measures on the basis of the likely impact on wind power development.

R2. Institutional requirements to facilitate wind power generation

Rationale Rapid development of windpower will be greatly facilitated by specialized institution with skilled manpower. The institution needs to be developed at several levels -- institutions at the state level (and below) will be required to install and maintain windfarms, identify new sites, design grid interfaces, prepare expansion plans/ reports etc. At a higher administrative level, institutions are required to formulate policies to encourage windpower development, arrange finances for the industry, and to facilitate the rapid development of windpower.

Objective: To design and recommend institutional arrangements for windpower development at various administrative levels.

R3. Manpower and capability building for wind power development

Rationale: Studies indicate that the land and wind resource availability are not the major constraints for windpower development. Lack of experienced and adequate manpower for preparation of specific project details would be a bottleneck. Preparation of detailed project reports require the identification of sites, modifications in existing grid. Actual execution of the projects also require skills and experience which would have to be developed. This are likely to be major constraints in windpower development at the scale envisaged.

In response to requirements of executing windfarms, the Tamil Nadu Electricity Board's has setup a *wind energy wing* with trained manpower (now, with substantial experience) capable of not only installing and maintaining windfarms, but is being able to identify new sites, design grid interfaces, prepare expansion plans/ reports and offer consultancy on wind power development. Replicating this, by setting up of a structure similar to the TNEB would benefit both Gujarat and Maharashtra and, in future, Kerala, where a number of good sites are indicated by the Wind Mapping project of the MoNES, where large scale wind power development is envisaged.

Objectives:

1 to draw a list of requirements for successful design and implementation of windfarms on the basis of the experience of Tamil Nadu Electricity Board, Gujarat State Electricity Board, and the Gujarat Energy Development Agency,

2 identify the skills needed to fulfill the requirements identified in (1) and to frame a capability building exercise to be undertaken in the states of Tamil Nadu, Gujarat, Maharashtra, Kerala, Orissa and other states that may be identified by the ongoing wind mapping exercise.

R4. Indigenisation of wind electric generation system

Rationale: The world production capacity would have to cater to the increasing demand from Europe, USA and other parts of the world. In Europe itself, a potential of 100,000 MW of windfarms has been identified to be met over the next 40 years or so. The highest turnover from the world wind turbine industry in the last decade has been of about 500 MW. The production capacity is likely to increase with an increase in demand but this increase again is limited and time dependent. In addition, with the likely cost effective potential in the country of the tune of 40,000-50,000 MW, considerations such as balance of payments, self reliance, etc. would indicate that indigenous wind turbine is a prerequisite to a large-scale wind power development.

The domestic production of wind turbines, at present, is restricted to BHEL. In addition, RRB Consultants, and NEPC are active in the windpower industry. Among the three active companies, BHEL has a strong engineering group and the requisite infrastructure for technology development. Under a MoNES sponsored project, BHEL has installed indigenously developed wind turbines. Both RRB and NEPC were believed to be considering production of wind turbines with partially imported components late last year. These developments need to be strengthened and a detailed indigenisation plan has to be developed for the wind power industry.

Objectives:

1 review the status of the wind engineering industry in the country,
2 identify the manufacturing needs of the wind electric technology,
3 assess if the manufacturing needs identified in (2) exist in any manufacturing industry in India,
4 recommend a detailed indigenisation plan for the wind power industry

R5. Small hydel

Rationale: In the mid seventies and the early eighties, the Rural Electrification Corporation (REC) estimated a potential of 5000 MW of small hydel potential in the country. Since then detailed project reports (DPRs) have been prepared for schemes aggregating to over 600 MW. Additional sites for over 1200 MW have been identified though their DPRs have not been prepared. The process for preparing the DPRs can be facilitated by an easy access to information of the identified sites and this process may also result in the upward revision of the REC estimates of the potential for small hydro in the country.

Objective:

1. Collate information on all small hydro sites identified,
2. Critically evaluate the information available and identify data gaps, and
3. Publish the information in a form so as to be accessible to all interested in small hydro development, particularly those interested in preparing DPRs.

R6. Capability building for designing and managing decentralized energy plans

Rationale: A close examination of the issues in rural energy planning suggested that effective energy intervention design in rural areas must be a component of the economic development plans of the area for which it is formulated -- integrating energy sources and technologies should not be the compelling factor. The purpose of the intervention design would be to augment and facilitate economically productive activities in addition to fulfilling the subsistence requirements and improving quality of life. Intensive intervention only in selected regions, implemented at the cluster of villages level, supervised from the Block, formulated from the district level, monitored at the state level and supported nationally appear to be the most promising combination for making effective interventions in the rural energy sector in the context of India. Formulating such intervention strategies, however, require skilled manpower at the district level.

Objective: Development of manpower capability at the district level for designing and managing decentralized energy plans.

R7. Developing alternate strategy for biogas implementation

Rationale: Considering the population and area and the constraint on financial resources available with the government, it is clear that government-sponsored interventions in the rural energy sector can, at best, play only a catalytic role. Logically, therefore, all rural energy programmes should be directed where the chances of success are the highest rather than to spread out too thin, particularly in the context of severe financial resource constraints in India. Regions requiring interventions would correspond to areas where energy (or the lack of it) is the felt need of the people. This approach also reduces the manpower required for post-installation service of technologies and is likely to facilitate the creation of a more effective post-installation service. Considering the fact that this has been a common and, perhaps, the most serious problem associated with the way national intervention programmes like the NPBD and NPIC have been implemented, this is likely to translate into substantial benefit for the diffusion of renewable technologies.

A need-based approach should be adopted rather than a target-oriented one This can be achieved only through integrating the plan for biogas development into an overall energy plan for a particular region or ecosystem instead of deciding targets in isolation. Such energy plans could then be integrated at a higher level for policy making, budget allocation, etc. Priority should be given to areas (disagregated to the district level for the obvious reason of ease in planning and implementing programmes form this level) where the lack of energy is perceptible

Objective·

1 to identify the districts in the country where biomass fuel (woody biomass, agricultural residues and animal waste) supply is likely to be in stress,

2 within district(s), prioritize the geographical clusters based on a methodology similar to that used in fulfilling Objective (1) and field surveys, and

3 estimate the potential in the clusters for biogas utilization after due consideration of animal dung and water availability, and, if possible, cattle holding.

R8. Designing effective biogas technology delivery systems

Rationale: Multi-agency approach adopted in the NPBD has provided rich experience of implementing rural energy interventions on a large scale. The biogas programme has been implemented, with varying degrees of success, by a wide range of agencies operating at differing geographical scales. These range from Khadi and Village Industries Commission (implementing programme at the national level), Gujarat Agro Industries Corporation (implementing at the state level), to the Block Development Officer (at the Block level) in the Government to Action for Food Production (at the national level), Gram Vikas (at the state level) to local level NGOs.

All agree that the delivery system for the biogas technology can be improved substantially and, to some extent, the programme is evolving along positive lines in many states and districts due to commendable effort at these level. There is, however, a need to learn from these experiences and to replicate them to the extent possible, as quickly as possible.

Objective:

1 identify effective organizations/ institutions involved in implementing the NPBD,
2 identify the features responsible for efficiency and effectiveness of these organizations/ institutions, and
3 based on (2), design an effective delivery for the biogas technology to the extent that the diversity of rural India permits.

R9. Study of the ownership profile of biogas technology

Rationale: Eligibility for installation of household biogas plant requires the household to possess the requisite number of cattle. Common grazing practices result in the requirement of at least 3 heads of adult cattle for the smallest (1 m^3) biogas plant and the possession of the requisite cattle heads implies a certain degree of affluence. Furthermore, there are scattered evidence of the ownership profile for the technology which suggest that the rural affluent are the major users of the technology. For instance, a study in Madhya Pradesh showed that most plant owners were affluent professionals such as doctors and lawyers. Another study reports only 2 to 5% of the biogas plant owners in Karnataka and Maharashtra, 10% in Marathwada and 20% in Gujarat belonged to scheduled caste and scheduled tribe communities. In Madhya Pradesh, none of the 775 plants surveyed belonged to a family from these categories.

The above observations would indicate that the NPBD may be subsidizing the rural affluent who can afford the technology without the government subsidy. It may, therefore, be worthwhile to commission a study to determine the profile of owners of the technology. Such a study may guide the policy on subsidies on the technology and help in a quicker commercialization of the technology without government support.

Objectives:

1 determine the economic profile of the owners of the household biogas plants through surveys in different states,

2 suggest the "marketing" strategy for the household biogas plant according to the "willingness-to-pay" for the technology for the different economic segments, and

3 based on (1) and (2), suggest the rationalization and/or removal of the subsidy policy for biogas technology

R10. Evolving design criteria for improved cookstoves

Rationale: A decade of implementing the cookstove programme has indicated that the expected levels of thermal efficiency increases expected (or desired) have not been achieved when a stove design is implemented There are numerous reasons for this, the most significant being the lack of information regarding the different cooking functions that the cookstove was required to fulfill. As a result, cookstoves unsuitable to the requirements of the area in which these were propagated were designed and failed to save fuel. There is, therefore an urgent need to gather more information on as cooking practices, the fuel and vessels used for cooking in addition to the cookstove and the functions that the cookstove performs.

This obviously, this is a mammoth task. To start with, areas can be selected on the basis of the desirable implementing strategy. The implementation strategy desired is similar to that outlined for the biogas technology and needs to be based on the premise that government-sponsored interventions in the rural energy sector can, at best, play only a catalytic role. The NPIC, therefore, should also be directed where the chances of success are the highest rather than to spread out too thin. In addition, studies indicate that improved cookstoves tend to be used properly and perform better in areas facing fuel scarcity.

Objectives:

1 identification of regions requiring interventions. These would correspond to areas where energy (or the lack of it) is the felt need of the people, and
2 study of the cooking energy system(s)
3 based in (2), work out the appropriate cookstove design(s) suitable to the cooking energy system in the identified region

R11. Identifying market segments for solar hot water systems

Rationale: Considering the overriding concern of commercialization, and the relative maturity of the solar hot water technology based on flat plate collector technology, there is an urgent need for designing and installing standardized

Since solar water heating systems appear to be cost effective only when hot water is required round the year, hotels and urban households satisfying this criterion (and using electricity for water heating) are the best target segment for domestic hot water systems.

R12. Solar cooker: user survey for product development and market segmentation

Rationale: The solar cooker manufacturing technology is reasonably mature. Efforts now need to be directed at developing user-friendly, marketable appliances. For example, a light-weight, single pot solar rice cooker with electrical back up might be eminently marketable. To determine the product requirements, however, a user survey and a market segmentation is required.

Since solar cooker is not a complete cooking system and supplements whatever cooking system is being used by saving fuel, the relevant target market are households using commercial fuels for cooking. As discussed, convenience (which includes availability of the fuel) plays a decisive role in determining the cooking technology choice. LPG is, therefore, the most preferred fuel choice. The widespread shortage of this fuel, much more severe in smaller towns, would indicate that the most attractive market segment would be households in such towns.

R13. Subsidies on solar thermal

Rationale: Experience indicates that commercialization is facilitated in a competitive market. In the energy sector the market is distorted due to large subsidies for most energy sources. Removal of subsidies to allow a healthier market for renewable technologies (particularly, solar thermal devices), though desirable, has to be viewed in an integrated energy pricing framework so that the competition between different energy sources is in a 'level playing field'.

Objective: Developing a long term Government support policy for solar hot water systems and solar cookers with the aim of gradual withdrawal of Government subsidy linked rationalization of prices for electricity and LPG, respectively.

R14. Programme of Research and commercialization of other attractive technologies

Rationale: The experienced with a large number of technologies utilizing renewable sources of energy has been mixed. The innovation in technology development, for many of these technologies has been disappointing. The main reason for this has been the dismal allocation for research and development. To some extent, however, even the limited financial allocations have not been efficiently utilized. Part of the reason for this is the absence of a long term programme of research with specific technology development goals within specific time-frames by specific research institutions. Such programmes of research are urgently required for attractive technologies with high potential such as

1. water pumping windmills,
2. biomass based gasifiers,
3. biomass based stirling engines,
4. solar ponds,
5. solar thermal cooling technologies based on evacuated tubular collectors, etc.

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